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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement page 36. 4990

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See half-page Advertisement, last and next week.

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See Full Page Advt. page 43, Nov. 17.

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SPECIALISTS. 4764
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MONOMETER MANUFACTURING CO., LTD.,
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See Advertisement page 52, Nov. 24.

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See Advertisement page 30, Nov. 24. 2602

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Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Centrifugals.
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MOTHERWELL, SCOTLAND. 5496
See half-page Advertisement page 74, Dec. 1.

The Manchester Steam Users' Association,

For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.
Chief Engineer: C. B. Stromeyer, M.I.C.E.
Founded 1854 by Sir W. Fairbairn.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 6109

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British School of Aeronautics, Aeroplanes and Airships. Construction, Design and Draughtsmanship. Complete Postal Courses. Also preparation for Exams. of Institutions of Civil, Mechanical and Electrical Engineers.—Pennington's, 284, Oxford Road, Manchester. 6307

TENDERS.

LONDON COUNTY COUNCIL.

The London County Council invites

Tenders for the Supply of

325 tons of ROLLED STEEL BAR for Magnetic Brake Shoes. The Form of Tender may be obtained from the Chief Officer, London County Council Tramways, 62, Finsbury Pavement, E.C. No Tender received at the County Hall after One p.m. on Tuesday, 19th December, 1916, will be considered. The Council does not bind itself to accept any Tender.

JAMES BIRD, F 657
Clerk of the London County Council.

TO MAKERS AND USERS OF LOCOMOTIVES

The MINISTRY OF MUNITIONS are prepared to receive

Offers for New or Good

Second-hand SHUNTING LOCOMOTIVES of various sizes.
The following information must accompany each offer, which must be addressed to Mr. HUBERT BAINES, Deputy Chief Engineer, H.M. Office of Works, King Charles Street, Whitehall, London, S.W.:—Type, size and weight; maker's name; when built; when and by whom last overhauled; condition; price.
H.M. Office of Works, &c.,
29th November, 1916. F 627

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—
CAST-IRON TANK PLATES, &c.
RAILWAY TICKETS, &c.
LEATHER BELTING, &c.
GALVANISED WATER CANS and MORTAR PANS.
CLOTHS, &c.
Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Cast-iron Tank Plates, &c.," or as the case may be, not later than Eleven o'clock a.m., on Thursday, the 14th December, 1916.
The Directors do not bind themselves to accept the lowest or any Tender.
R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, London, E.C.
6th December, 1916. F 687

In the Matter of Trading with the Enemy Act, 1916.

THE A. E. G. ELECTRIC COMPANY LIMITED.

Clearance Sale of Stock, in

ONE LOT,
OF ELECTRICAL ACCESSORIES
BY PUBLIC TENDER,
by order of the Controller, Mr. Maurice Jenks, F.C.A. (Messrs. Maurice Jenks, Percival & Co.), THE ENTIRE STOCK OF MOTORS, INSTRUMENTS, FITTINGS, and ELECTRICAL ACCESSORIES will be sold by Public Tender
IN ONE LOT.
The goods are on view upon the premises, Richmond Mews, Dean Street, Soho, London, W., and may be inspected upon production of Catalogue, to be obtained gratis from the Selling Agents for the Controller, WHEATLEY KIRK, PRICE & CO., 46, Watling Street, London, E.C.
Tenders must be delivered to the Selling Agents on or before Noon, Friday, the 15th December, 1916. F 652

CORPORATION OF CALCUTTA.

NOTICE TO CONTRACTORS.

Tenders are Invited, in

duplicate, for STORM WATER PUMPING PLANT, and will be received by the Deputy Chairman of the Corporation up to Two p.m., on Friday, the 1st June, 1917, when they will be opened in the presence of such tenderers as may be present. Each Tender, in duplicate, must be enclosed in a sealed cover and superscribed, "Tender for Storm Water Pumping Plant." Further particulars may be had by applying to the Chief Engineer, Municipal Office, Calcutta. Specification, with site drawings, contract agreement, Tender form and rules with regard to Tenders, may be obtained from the office of the *Indian and Eastern Engineer*, 50, Fenchurch Street, London, England (or at Calcutta, from the Secretary to the Corporation), on payment of Ten Shillings for each combined copy. Tenderers must abide by the Corporation rules in regard to Tenders. Tenders must hold good for at least two months from the date of opening of the same.
C. C. CHATTERJEE,
Secretary to the Corporation.
Central Municipal Office,
23rd October, 1916. F 554

APPOINTMENTS OPEN.

Chief Engineer of Experience

and capable of taking charge of large works, conversant with the various types of engines, boilers, motors, lighting and heating, suitable for the textile trade.—Address, stating wages required, age and previous experience, F 666, Offices of Engineering.

IMPORTANT POSITION VACANT.

First-class Works' Managers

are invited to apply for VACANCY which will shortly occur in a large Government controlled Engineering Works having foundries, machine shops and erecting bays, specialising in high-class work of repetition nature, both small and large. The appointment is an important one, and a high salary offered accordingly. Applicants must have wide experience in works organisation and up-to-date methods, be strict disciplinarian, and able to secure maximum output; must have successfully filled similar position in Engineering Works of not less than two or three thousand hands.
Address, in first instance, giving full particulars, which will be treated as confidential, F 509, Offices of Engineering.

Works' Manager Required

for Government controlled firm, to take charge of new extensions in course of erection. Must be able to see that erection of buildings and putting down of machine plant is accomplished with the utmost speed, and be conversant with the latest up-to-date machine practice for taking control of the extensions when completed; also must be able to take charge of a large body of men and maintain strict discipline. Only first-class energetic men need apply. Applications will be treated as strictly confidential.
Address, F 690, Offices of Engineering.

Works Manager Wanted for

General Engineering Works at present chiefly engaged in shell manufacture and employing about 600 hands. Must be six o'clock man and a capable and efficient manager of men and women workers. Intimate knowledge of modern machine tool practice essential. District near Bristol. Good opening for suitable man. No one at present engaged on War work need apply without permission from present employer.—Write, stating full qualifications, age, and when at liberty, to BOX No. 883, care of Messrs. R. F. White & Son, General Advertising Agents, 83, Fleet Street, E.C. F 573

British Municipal Council,

TIENTSIN, NORTH CHINA.—The Council is prepared to receive APPLICATIONS from British subjects for the POST of MUNICIPAL ENGINEER. Candidates will be required to pass a medical examination as to their physical fitness for the position.—Applications should state age, qualifications, salary required, &c., and should be forwarded, together with copies (not originals) of testimonials and particulars of previous employment and experience, on or before December 31st, 1916, to F 449, Offices of Engineering.

Assistant to Managing-

Director REQUIRED, by an aeroplane manufacturing company (1000 employees), to deal with purchasing and manufacturing departments and sub-contractors' orders. For a really energetic and capable man with good administrative, commercial and engineering experience, there would be excellent prospects and remuneration.—Applications should be forwarded, giving age and full particulars of past experience, to 1231, Sells' Advertising Offices, Fleet Street, London. F 668

Engineer Foreman for

Controlled Works; capable of superintending repairs and erection of boiler works plant, and take charge of small fitting shop, making-up pressing, and rolling machinery; one with some knowledge of electric motors, hydraulic presses and gas engines preferred; permanent position to right man. State age, wages, and experience, for Wolverhampton district; no one on Government work need apply.—Apply, nearest LABOUR EXCHANGE, mentioning this Journal and F 536.

Engineer Wanted to take

complete control of Boiler Plant, consisting of 30 Lancashire Boilers, at large new paper mill near London. Must have had considerable experience in boiler repairs and working of water-softening plants. Preference given to man with up-to-date knowledge of boiler-house economics. Commencing salary, £300 or upward, according to qualifications. Permanency for suitable man. Candidates must be ineligible for military service.—Apply, in first instance, with copies of recent testimonials, and giving full particulars of qualifications and salary desired, to THE CHIEF ENGINEER, National Boiler and General Insurance Company, Limited, Manchester. F 644

Refrigerating Engineer

WANTED; experience, with ammonia and first-class Board of Trade Certificate desirable. No one already engaged on Government work or eligible for military service need apply.—Send particulars of experience, with age, and state if married, to "T." BOX 252, T. B. Brown's Advertising Offices, 163, Queen Victoria Street, E.C. F 608

Three Marine Engineers

WANTED to take shift duty in boiler house of large provincial electric supply undertaking. Wages £3 per week. Only those finally rejected for military service or over military age will be considered.—Address, stating age and full particulars of experience, F 661, Offices of Engineering.

Works Engineer for Sheet

Mills in South Staffordshire; must be thoroughly competent in all branches. No person already engaged on Government work will be employed. — Apply, your nearest LABOUR EMPLOYMENT EXCHANGE, mentioning this Journal, and F 607

COUNTY BOROUGH OF WEST HARTLEPOOL.

TECHNICAL COLLEGE.

Temporary Assistant Teacher

(ineligible for military service) REQUIRED in the Mechanical and Marine Engineering Department.
Laboratory, workshop, and teaching experience desirable.
Salary, £180 per annum.
Further particulars may be obtained from the undersigned.
Applications, together with two testimonials, to be sent in before the 6th December, 1916.
J. G. TAYLOR,
Secretary.
Education Offices,
West Hartlepool,
27th November, 1916. F 591

Production Expert Wanted,

in a Government controlled establishment engaged on the manufacture of Motor Transport Vehicles. Experience in the modern methods of production and the designing of Jigs, Tools and Fixtures essential.
Applicants should apply to the nearest EMPLOYMENT EXCHANGE giving particulars of experience, age and salary required, mentioning this Journal and No. A 2646.
No man at present on Government work need apply. F 642

Practical Steel Foundry

EXPERT REQUIRED to organize new steel foundry, weekly output 60 to 80 tons. Electrical furnaces will be installed, and the work will be mostly repetition work for motor lorries. Replies to give full details as to age, practical experience, and salary required.—F 590, Offices of Engineering.

First-class and Fully Qualified

Stores ACCOUNTANT WANTED, at once, for large factory. Must be experienced in all duties appertaining to stock-keeping and stores accountancy; also accustomed to prime costing. Preference given to applicant holding C.A. or other similar certificate. State full particulars and salary required.—Address, F 511, Offices of Engineering.

Experienced Draughtsmen

REQUIRED, for general engineering work, Birmingham district, to assist in development of processes and efficiency work. Permanency to suitable men. State full details as to experience, age, salary expected, and when free. No person already on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 2610. F 686

Wanted, Three Draughtsmen

thoroughly conversant with either Blast Furnace or Steel Works practice, for large Government controlled Iron and Steel Works on the North West Coast. Permanency to suitable men.—Applications should be forwarded to the nearest LABOUR EXCHANGE, quoting No. A 2322. Draughtsmen already engaged on Government work cannot be engaged. F 394

Wanted, Several Good

DRAUGHTSMEN, with mechanical engineering experience. No person resident more than 10 miles away, or already employed on Government work will be engaged.—Reply by letter, giving full particulars, age, experience and salary required, to The SOPWITH AVIATION CO., Ltd., Kingston-on-Thames. F 358

Draughtsman (Engineering)

REQUIRED, for large factory North of England. Persons already employed on Government work will not be engaged. Applicants must state position under Military Service Act.—Reply fully, to nearest LABOUR EXCHANGE, mentioning this Journal and F 654.

Wanted, Draughtsman for

the mechanical design of large electrical direct current machines. Nobody engaged on Government work will be accepted.—Write or apply to the nearest BOARD OF TRADE EMPLOYMENT EXCHANGE, mentioning this Paper and No. A 2631. F 695

Wanted, a Draughtsman to

take charge of turbine work in the drawing office of a large marine engineering works.—State age, experience, and salary required to nearest EMPLOYMENT EXCHANGE, quoting No. A 2681. No person already engaged on Government work can be engaged. F 641

Draughtsmen Two (preferably

young), ineligible, REQUIRED by Engineers, S.E. London. No applicants not residing within a radius of 10 miles, or already employed on Government work can be engaged.—Address, stating full particulars, age, and salary required, F 637, Offices of Engineering.

Draughtsman Wanted, Mech-

anical, for small pencil details and finished ink drawings; also RAPID TRACER and good letterer. Both must be ineligible for military service.—Reply, stating age, experience, and salary required, to 1231, Sells' Advertising Offices, Fleet Street, E.C. F 647

Draughtsman.—Wanted, for

Jigs, Tools and Fixtures for Automobile details in Government controlled establishment. Previous experience essential. State age and salary required.
No man at present on Government work need apply.
Applications in the first instance, should be made to the nearest BOARD OF TRADE EMPLOYMENT EXCHANGE, mentioning this Journal and No. A 2647. F 643

Draughtsman, British,

thoroughly conversant with mechanical and electrical machine construction, REQUIRED, to take charge of Engineer's drawing office, Westminster. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and F 676.

Wanted, Mechanical

DRAUGHTSMEN used to general engineering and detail work of steam plant, for large engineering firm, Manchester district. Must be ineligible for army. Good opportunity for first-class men. Apply, stating experience, age, and salary required to your nearest EMPLOYMENT EXCHANGE, mentioning this journal and F 676. No person already on Government work will be engaged.

Draughtsman, good mechani-

cal, preferably with experience of steam turbine design. No man on Government work need apply.—Apply, stating qualifications, age, salary required, and earliest date can commence, to your nearest BOARD OF TRADE EMPLOYMENT EXCHANGE, mentioning this Paper and No. A 2676. F 663

Draughtsman Wanted in

Engineers' Shop in Eastern district; permanency for suitable man. State qualifications, experience and salary required.—Address, F 635, Offices of Engineering.

Wanted, Several Jig and

Tool DRAUGHTSMEN, used to designing jigs, fixtures, tools and gauges for repetition work. No person already on Government work will be engaged. Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 2654. F 668

Wanted, Mechanical

DRAUGHTSMAN, having good theoretical training and shop experience, for large Aeroplane Works; Aeroplane Draughtsman preferred. No one at present on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and F 670

Draughtsman Wanted by

certified undertaking, preferably used to boiler, pipework, and power station foundations and layouts.—Apply, by letter, to the YORKSHIRE POWER COMPANY, Wellington Road, Dewsbury, stating age, whether ineligible, wages required, and when at liberty. F 689

Assistant Draughtsman

WANTED, for Marine Auxiliary Machinery. State experience and wages expected. No person already engaged on Government work or residing more than 10 miles away need apply.—Apply by letter, to CAIRD & HAYNER, 111, Commercial Road, Limehouse, E. F 563

Junior Draughtsman Wanted,

for general engineers work. Good wages and War Bonus. No one on Government work will be employed.—Apply to your nearest EMPLOYMENT EXCHANGE, quoting No. A 2682. F 675

Wanted, a First-class

DESIGNER of small and medium size A.C. and D.C. motors, for the London District, preferably one with American and Continental experience, and who has previously developed complete lines of machines.
Good opening for a thoroughly experienced man. No person already engaged on Government work need apply.—Write or call your nearest EMPLOYMENT EXCHANGE, giving full particulars and copies of testimonials, stating salary required, age, and when at liberty, and quoting No. A2683. F 674

Wanted Lady Tracers, or

with experience in Detail Drawing, &c.; must be quick and accurate. No one employed on Government work will be entertained.—Please apply to the nearest EMPLOYMENT EXCHANGE, sending full particulars and sample of work, mentioning this Journal and F 660.

Wanted, by a Yorkshire Firm

of Engineers, TWO GOOD FOREMAN MACHINISTS. No person already employed on Government work will be engaged.—Apply, stating age, salary required, and full particulars, to your nearest LABOUR EMPLOYMENT EXCHANGE, mentioning this Journal and F 656.

Wanted, for Controlled

Works, FOREMAN over heavy and medium lathes and machines on hydraulic work and gas engines. No one already employed on Government work will be engaged.—Apply, stating previous and present employers, age, experience, and salary, your nearest LABOUR EMPLOYMENT EXCHANGE, mentioning this Journal and F 673

Storekeeper Required, for

large factory North of England. Must have had first-class experience and be capable of handling large stores. Persons already employed on Government work will not be engaged. Applicants must state position under Military Services Act.—Reply fully, to nearest LABOUR EXCHANGE, mentioning this Journal and F 653.

Assistant Required for

Mechanical Department of Mine in Portugal. Qualifications: all-round experience, especially on large repairs; railway and mining machinery, good draughtsman; a knowledge of Portuguese or Spanish advisable; also of gas engines and electrical plant. Salary, £18 per month first, £19 second, and £20 third year; travelling expenses and furnished quarters.—Send full particulars immediately to Dr. J. S. OWENS, 47, Victoria Street, Westminster. F 650

Young Engineer with Work-

SHOP Training and Science Degree WANTED for technical work in large instrument making factory. No one engaged on Government munition work or eligible for military service should apply. State age, experience and salary required.—Apply your nearest EMPLOYMENT EXCHANGE mentioning No. A 2694. F 631

Wanted, Four Women Oper-

ATORS with a knowledge of ferroprussiate and true-scale processes. Women already in Government employment or in a controlled establishment under the Munitions Act can only be accepted with the approval of the authorities of their department or establishment.—Apply by letter to Room 344, Admiralty House, Victoria Embankment, E.C., stating experience, age, and salary required. F 645

Engineering Pupil.—Vacancy

with Firm (Government Contractors) manufacturing latest types of machinery, oil and gas engines, &c.; moderate premium.—Address, 6521, Offices of Engineering.

A Large Firm of Engineers,

in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4300, Offices of Engineering.

SITUATIONS WANTED.

Mechanical Engineer (36),

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LITERATURE.

Cleator and Cleator Moor: Past and Present. By CÆSAR CAINE, Vicar of Cleator. Illustrated. Kendal: Titus Wilson. [Price 21s. net.]

IT is not often that in these columns we are called upon to comment on the literary results of those who indulge in archæological research, or allow ourselves the luxury of looking backward to note the changes that accompany development. The Rev. Cæsar Caine, however, in this book blends the present with the past, and we would not if we could overlook his careful reconstruction of the tranquil history of a picturesque and somnolent village, where

> "Light labour spread her wholesome store,
> Just gave what life required, but gave no more."

Time in this village has worked a metamorphosis that to some may be painful. The mining industry, and especially the deposits of hematite, in sufficient quantity to be commercially valuable, changed this peaceful scene into one of struggle and animation, and the author leaves us to study the contrast and draw our own conclusions. Engrossed in the more strenuous present, chronicling the results of ingenuity and activity, we need not deprive ourselves of the pleasure of tracing the successive steps that have converted the leisurely country-side, with its babbling brooks and cultivated fields, into a busy manufacturing centre offering new opportunities to struggling ambition and larger prizes to continuous enterprise. The vicar of Cleator tempts us to look back into the far past and learn how people lived and died when time was young, how they were governed legally and socially; educated, technically and religiously; played and worked; wrestled and coursed, amid the secluded Cumbrian Hills lying between St. Bees and the Ennerdale Lake.

The author also fills in a middle-distance picture by sketching the early days of the Cleator Moor Ironworks, and depicts a district, tame but not uninviting, that supported a few families whose names and merits are even now to be traced, but whose members have disappeared in the urgent bustling needs of the mining and smelting industries, that brought an influx of artisans and workers from afar, foreign to the healthy and simple Cumberland life. For some 30 years progress is rapid as judged by mining statistics, but from an agricultural point of view the tale is not such pleasant reading. Districts that had been ploughed right up to the sky-line lost their character and their productiveness. There is only one cornfield on the mountain side at the present time, says the vicar, and one cannot but regret the sacrifices that were demanded and paid in order to satisfy the hungry cravings for the hematite ore. Streams that worked mills and were a useful source of power to the agricultural community disappeared. The greedy mines, the constant boring, shaft-sinking and level driving all over the area tapped the sources of ancient streams that once found useful employment, and the water takes its way underground. Not only the water but solid buildings have been swallowed up in the subsidences caused by mining operations under their sites. Foundation walls, roofing slates and chimney pots, every stick and stone, sank into the yawning gulf opened beneath, and the people who long lived under the roof-tree have disappeared as completely as the property. These are the tolls that have to be paid for industrial progress, and it is well sometimes to see the other side of the picture. The careful piecing together of old materials that tell of family history and departed worth is not without its charm.

The geology of the district as well as the people is described by the author, but his acquaintance with the former is apparently not so intimate, and much of his information concerning the ore bodies around Cleator is drawn from treatises rather than from actual examination. Guided by authority, he accepts the theory of metasomatic replacement as sufficient to explain the origin and main features of the ore encountered on Cleator Moor, but he does not readily forsake the long-held and perhaps simpler suggestion of deposition in fissures by some process of igneous injection. We regret that with his opportunities for thorough systematic examination, Mr. Caine has not been able to collect some decisive evidence in favour of the hypothesis that the deposit is the result of a chemical action by which the limestone rock has been removed and hematite substituted. The evidence from pseudomorphs, as reproduced here, is inconclusive. The key of the problem lies in the limestone formation found between the coal measures in the west and the Skiddaw slates of the Silurian order in the east. Close to the Cleator boundary this limestone can be explored and investigated without great difficulty, and it might be possible to trace through successive stages the gradual change in the character of the deposit from the limestone of the district into the chalybite or the hematite. Both these forms of the ferrous carbonate and the ferric oxide have been mined at Cleator. The anhydrous ferric oxide, hematite (Fe_2O_3) is found in several forms, but the botryoidal concretions known as "kidney" ore are apparently the most common. This ore consists of reniform masses, varying in size, "easily scratched by a file; lustre earthy; colour purplish-grey; streak bright red; fracture uneven; containing cavities lined with crystals of specular iron, and containing in some cases quartz." The ferrous carbonate occurs in two forms, either as spathic ore, small curved rhombohedra, resembling dolomite, or mixed with clay and bitumen.

In some places the hematite ore has been brought so near to the surface that the mine can be worked as an open quarry, the overburden being not more than 15 or 20 ft. thick. Under such circumstances the hematite consists of a bed varying from 15 to 30 ft. in thickness, and is for the most part a dense mass of red ore, subdivided by irregular and nearly vertical joints. This is the description of only one bed, but all through the district the hematite is abundant, and though some beds have been exhausted and the working of others may not prove remunerative, yet the industry has extended into other neighbouring areas, so that it is difficult to explain the steady decrease in output in the last 40 years. The author is more interested in tracing the changes wrought by the mine working, and in doing justice to the local worthies who have exploited the mines, than in explaining the causes of their decline. One would have liked to hear more of the methods of smelting employed, and the changes to which the processes have submitted in comparatively recent times. But the author is not a metallurgical engineer, his object is not to follow with any minuteness the changes that have been introduced; his antiquarian tastes are better satisfied by tracing back the history of the mining industry into the distant past, when the methods of smelting were crude and charcoal was largely used. His archæological researches have convinced him not only that in the days of the Plantagenets were there references to iron mining in the archives of Furness Abbey, but that some of the shallow deposits were worked much earlier. Vigorous work, however, seems to have been initiated about 1840, and the increase of output was for a time rapid. But the best mine is a wasting asset, and the decline has been as rapid as the rise, as shown in the accompanying table:—

Decade.	Output in Tons.
1871–1880	4,505,951
1881–1890	3,508,899
1891–1900	2,165,333
1901–1910	1,266,208

In the face of these figures it is hard to take a hopeful view of the future, but the author cannot persuade himself that the prosperous days of Cleator are to be numbered with the past. He concludes that the present mines will continue to be worked for many years to come, and looks forward to a time when the flourishing conditions that favoured Cleator will be renewed in contiguous districts. Just as he has reconstructed the past and surveyed the present, so he seeks to penetrate the future and offers us a final picture in which the capitalist with large means and equal courage is seen boring through the coal measures overlying the carboniferous limestone and finding a due reward in unearthing the concealed ore treasures. In those halcyon days we may hope that the large number of Cleator miners who have forsaken the village, either from necessity or choice, tempted by the lure of high wages, may return to their homes and families. This sad and curious separation is a striking feature in Cleator life. The social status of the miner necessarily interests its vicar greatly, and his description of the homes held together by the mother in the absence of the breadwinner, the discipline maintained, the capacity exhibited, the fearless contest with hardship, makes cheerful reading in these days, when we know that owing to the war many homes will be deprived of the father's guidance and many a child made solely dependent on its mother's care and direction.

We part with Cleator and its people—aye, and with its vicar—with regret. He tells us that he has delved so thoroughly into the past that the old families whose names exist only on the tombstones of the churchyard are at times more real to him than are his own parishoners. In the same way he has so artfully brought before us the scattered homesteads on the lonely moor that existed before the dreary streets were hurried up to meet the demands of immigrants to the rising factories, that we can picture the town and its surroundings more clearly than others with which our acquaintance has been closer. On the fields round about the flax plant once grew and the spinning mill was the nucleus of a flourishing industry, which still survives in the works of the Linen Thread Company. But that was before the days of smelting, when Cleator was well described as one of Nature's solitudes. The developments wrought by time are typical of many another village, whose rise and culmination have followed some lucky chance, some happy combination of circumstances, till competition destroys the favourable conditions and a period of comparative stagnation supervenes, only to be succeeded by the sure evidences of decay. Whatever fate may overtake Cleator, its vicar has rescued its history from oblivion and left us a vivid picture of its industrial fluctuations that will interest alike the economist and the social historian of the future.

A System of Physical Chemistry. By WILLIAM MCC. LEWIS, M.A., D.Sc., Brunner Professor of Physical Chemistry in the University of Liverpool. Two volumes. London: Longmans, Green and Co. [9s. net, bound.]

THE "System of Physical Chemistry" is one of the best and most useful of the series of Text-Books on Physical Chemistry edited by the late Sir William Ramsay, under whom Professor Lewis was lecturer in physical chemistry at University College, London, before succeeding Professor Donnan at Liverpool. The term physical chemistry has barely enjoyed 30 years of academical recognition as a lecture and text-book subject. Before Ostwald was appointed professor of physical chemistry at Leipzig in 1887 and founded the Zeitschrift für Physikalische Chemie, physical chemistry was taught and studied under special headings falling into the domains of theoretical chemistry and physics. We should be embarrassed to say which parts of theoretical chemistry are outside the field of physical chemistry. Professor Lewis does not delineate the boundaries of his subject. He simply states in his preface that he does not, in these two volumes, deal with the relations of physical properties to chemical constitution and other purely stoichiometrical relations, because they form special subjects, which Sydney Young, Samuel Smiles and others have treated in books of the same series. That means that valency and isomerism, for example, are not discussed. On the other hand, Professor Lewis includes sufficient accounts of recent theoretical investigations, still speculative, but affecting almost every problem, such as the structure of the atom, capillary chemistry, the quantum theory, Nernst's heat theorem, and he deals with his wide subject in so systematic and broad a manner as to justify his title "A System of Physical Chemistry."

The essence of his system is the following. He regards all physico-chemical phenomena as admitting of separation into two classes: firstly, phenomena exhibited by material systems when in a state of equilibrium; and secondly, phenomena exhibited by systems which have not yet reached a state of equilibrium. Every conceivable material system must belong to one of the two classes. By emphasising this leading idea, Professor Lewis obviates the selected-chapter method of treatment and guards the essential unity of his subject. The scientific treatment is based upon the kinetic theory, which accentuates the actual molecular mechanism

of a process, and upon the theory of thermodynamics, accentuating the energy changes involved. Not at once to confront the reader with the most difficult part of the subject, the fundamental principles of thermodynamics and statistical mechanics, he divides his book into three parts. In the first he treats the phenomena only from the "classical" kinetic standpoint, in the second from the thermodynamic standpoint, in the third from the standpoint of thermodynamics and of the new "modified" principles of statistical mechanics. Part I constitutes Volume I, Parts II and III are embodied in Volume II. The treatment may appear to involve repetitions; but matters had, of course, to be elucidated from both the standpoints. Part III—and also Part II—concerns modern conceptions, about which very little has been so far found in text-books, and any overlapping is rendered unobjectionable by the good index and copious cross references. In the thermo-dynamic treatment the concepts of maximum work and of free energy have been employed by preference to the concept of entropy, which is less easy to grasp—"though this must ultimately be something of a mental delusion, I suppose." The system of classification upon which Professor Lewis bases his exposition does not really consist in the division into three parts, which is a concession to practical considerations, made also for the purpose of rendering the book as readable as possible from the student's standpoint. His general system of classification is indicated in the chart which forms the frontispiece of Volume I. The appreciation of this chart presumes a general knowledge of physics and chemistry. Professor Lewis, indeed, presupposes that knowledge throughout his book, but he fully and clearly explains matters and does not merely attach explanatory notes to special points. He gives abundant references, occasionally quoting characteristic passages in the investigator's own words or in their English equivalent.

Part I opens with a chapter on the kinetic molecular constitution of matter and molecular dimensions and passes on to a consideration of the evidence for the real existence of molecules; in the account of Perrin's determination of Brownian movements, which was based upon Einstein's considerations, there is a long quotation from Einstein, but it is not clear where the quotation ends. Brief references are made to the hypotheses of J. J. Thomson and of Nicholson on the structure of the atom, but not to the views of Rutherford and Bohr; the remarks on transmutation of elements might be more critical. The further discussion of the behaviour of gases in space leads to the consideration of the continuity of state according to Andrews and James Thomson and to the equations of state of Ramsay-Young, van der Waals, Clausius and Dieterici. These first two chapters take up 112 of the 510 pages of the first volume, and much of this ground is again traversed in the thermodynamical considerations of Volume II. Professor Lewis gives a heading to each page, and we find in these headings, for instance, a distinction drawn between gas reactions of the first type (in which the total number of molecules remains unchanged) and of the second type (in which there is a change in the number of molecules); but these useful headings are not embodied in the table of contents, which is too sketchy.

We will indicate the way in which Professor Lewis introduces the heat theorem of Nernst and will first refer in this connection to what he says on maximum work. In the chapter on chemical affinity he points out (after van't Hoff) that the only true measure of the chemical affinity between two substances, which manifests itself by chemical reaction when the substances are brought into contact, is given by the maximum external work, at constant temperature and at constant (or practically constant) volume, which is done by the system in passing from the initial state to the state finally reached by the reaction, *i.e.*, the equilibrium point. When a volume change takes place, the work term this change involves has to be subtracted or added; what results is the chemical affinity. The term "principle of maximum work" had unfortunately been used by Thomsen (1854) and especially by Berthelot (1867) in another sense, to indicate the direction in which a reaction would take place. Berthelot thus made the heat effect the determining factor. Hydrogen and oxygen, he argued, will combine when ignited because heat is developed by their combination; whilst nitrogen and oxygen do not combine, but tend rather to decompose, if brought into combination by indirect means, because their combination takes place under absorption of heat. In other words, Berthelot's principle postulated the existence only of exothermic (not endothermic) reactions. Although soon disproved, this principle survived in text-books for a long time.

To approach the theorem, we have to go back to the introductory chapter on thermodynamics and to the distinction between A, the free or available involved in a reaction, and U, denoting the change in internal (or total) energy. According to the first law, Professor Lewis points out, the decrease (denoted by + U) in the internal energy taking place during a reaction must be equal to the external work A (done, say, in increasing the volume against pressure) plus the amount of heat evolved (calling the heat absorbed + Q, and the heat evolved − Q) so that $U = A + (-Q) = A - Q$. The free energy of A, measured by the maximum work done in isothermal change, may partly be due to the system itself and partly to the surroundings; the change in total energy has its origin in the system itself, and the U is identical with ± Q, the heat absorbed or evolved in the reaction at constant volume. The relations between these quantities are by no means obvious. The earliest assumption of Joule and W. Thomson was that $A = -Q$; they found this view fairly borne out in the case of the reaction going on in the Daniell cell, $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$. That agreement was, however, due to the fact that the reaction, and hence the electromotive force of the Daniell cell, has practically no temperature coefficient. Yet approximately that equality holds, especially at ordinary temperature, in reactions between solids and liquids (so-called condensed systems), because ordinary temperature is not much above absolute zero—comparatively speaking, when one thinks of the high temperatures of gas reactions. The true relation was given by the Gibbs-Helmholtz equation $A - U = T\,(d\,A/d\,T)_v$, the volume being supposed to be kept constant in the differential. According to this equation A must equal U when there is no temperature coefficient, and also at absolute zero when $T = 0$. When A and the differential can be measured, U can be calculated; but the observation of U does not suffice to determine A. When the equation is slightly modified and integrated, it yields

$$\frac{A}{T} = a - \int_0^T \frac{U}{T^2}\,d\,T.$$

The U varies with the temperature at which the reaction is made to take place, and can be expressed in terms of U_0 (the value of U for $T = 0$) and a series of terms containing powers of T. This, however, is only possible for condensed systems—as Professor Lewis emphasises—and the constant *a* cannot be determined.

It is here that the heat theorem of Nernst steps in; he shows how to evaluate *a*. Nernst points out that A and U are fairly equal to one another at temperatures near absolute zero, and that the curves of $d\,A/d\,T$ and $d\,U/d\,T$, which converge, nearly coincide before they reach zero. The argument again holds only for condensed systems, because gases no longer exist at absolute zero; but the affinity of a reaction occurring in a gaseous system (or in a dilute solution) can be calculated from the affinity and heat relations for the same reaction when it occurs in the solid state. Hence it should be possible to deduce A from determinations of U, measurements of Q and of the specific heats. The hypothesis cannot really be verified; for measurements of A and U cannot be carried out near absolute zero. Very low temperatures can, however, be obtained experimentally, and Nernst considers extrapolation justifiable. The rapid fall in the specific heat—and therefore in the difference between the specific heats of the liquid and solid—which he assumes to take place at low temperatures, was actually observed, *e.g.*, by Koref (one of Nernst's collaborators) in the case of benzophenone, which admits of strong super-cooling; the difference was 0.0774 at 295 deg. absolute and 0.0012 at 137 deg. absolute. Professor Lewis proceeds to show how the Nernst theorem has been applied, for the purpose of deducing the A from the U, to the energy change involved in the transformation of rhombic into monoclinic sulphur, to the determination of fusion temperatures (benzene), of the affinity of water for certain salts, of electromotive forces of voltaic cells consisting of liquids or solids (*e.g.*, lead, lead chloride, silver chloride, silver—all solid), of equilibrium in homogeneous gaseous systems, to the dissociation of water vapour, the Deacon process (chlorine from hydrochloric acid and oxygen), and the determination of equilibrium in heterogeneous systems (gas-liquid or gas-solid). Most of the results of these applications are in agreement with other data as far as available.

In similar ways Professor Lewis expounds in the short Part III the considerations which forced the quantum theory on Planck and the extension of the theory by Einstein and Debye concerning specific heat and atomic heat calculations. Part III further deals with photo-electricity and residual rays (Reststrahlen). It might be objected that Professor Lewis gives undue prominence to controversial or speculative matters, such as the heat theorem, in a text-book for students. But we have noticed the theorem because it is new to text-books and to our columns; we might equally well have picked out the phase rule, for example, for special consideration. Professor Lewis, moreover, does not give prominence to these matters; his exemplifications are quite as instructive as his theoretical deductions, and he does not write for junior students. We should have liked to find more and more recent information concerning steam and saturated steam. We miss a few names connected with original research from the text and from the index of authors. But one could not fairly charge Professor Lewis with omissions. His system of physical chemistry is unusually comprehensive and complete in subject matter and in references; it is conscientious work throughout, and we can warmly recommend it.

BOOKS RECEIVED.

Manual of Electrical Undertakings and Directory of Officials. 1916–1917. Compiled under the direction of Emil Garcke, M.I.E.E., F.S.S. Vol. xx. London: Electrical Press, Limited. [Price 21*s.* net.]

The Gas Works Directory and Statistics, 1916–1917. London: Hazell, Watson and Viney, Limited. [Price 10*s.* 6*d.* net.]

Practical Shipbuilding: A Treatise on the Structural Design and Building of Modern Steel Vessels. By A. Campbell Holms. In two volumes. Vol. I, Text: Vol. II, Diagrams and Illustrations. Third edition. London: Longmans, Green and Co. [Price 52*s.* 6*d.* net.]

The Daily Mail Year Book for 1917. Seventeenth year. Edited by David Williamson. London: Associated Newspapers, Limited. [Price 1*s.*]

United States Department of the Interior. Bureau of Mines. Bulletins. No. 91: *Instruments for Recording Carbon Dioxide in Flue Gases.* By J. F. Barkley and S. B. Flagg. No. 102: *The Inflammability of Illinois Coal Dusts.* By J. K. Clement and L. A. Scholl, Jr. Washington: Government Printing Office.

United States Department of the Interior. Bureau of Mines. Technical Papers. No. 113: *Some Properties of the Water in Coal.* By Horace C. Porter and O. C. Balston. No. 126: *The Casting of Clay Wares.* By Taine G. McDougal. No. 134: *Explosibility of Gases from Mine Fires.* By George A. Burrell and George B. Oberfell. Washington: Government Printing Office.

The Book of the Ford. By R. T. Nicholson. London: Temple Press, Limited. [Price 1*s.* 6*d.*]

Elementary Mathematics for Engineers. By Ernest H. Sprague, A.M.Inst.C.E. London: Scott, Greenwood and Son. [Price 4*s.* net.]

Flood Absorption in Tanks. By S. K. Gurtu, M.A. Gwalior: Alijah Darbar Press. [Price 3–8 rupees.]

General Cargo: An Introduction to Salesmanship. By Richard E. Goddard. London: Constable and Co., Limited.

The Portland Cement Industry. By William Alden Brown. London: Crosby Lockwood and Son. [Price 7*s.* 6*d.* net.]

Union of South Africa. General Report of the Miners' Phthisis Prevention Committee. Pretoria: The Government Printing and Stationery Office.

Metals for War Munitions.—The Ministry of Munitions has forwarded the following for publication:—The Minister of Munitions has appointed a committee, under the chairmanship of Mr. C. W. Fielding, to advise him upon the steps which can be taken to secure the most economical use of the metals required in the manufacture of munitions of war.

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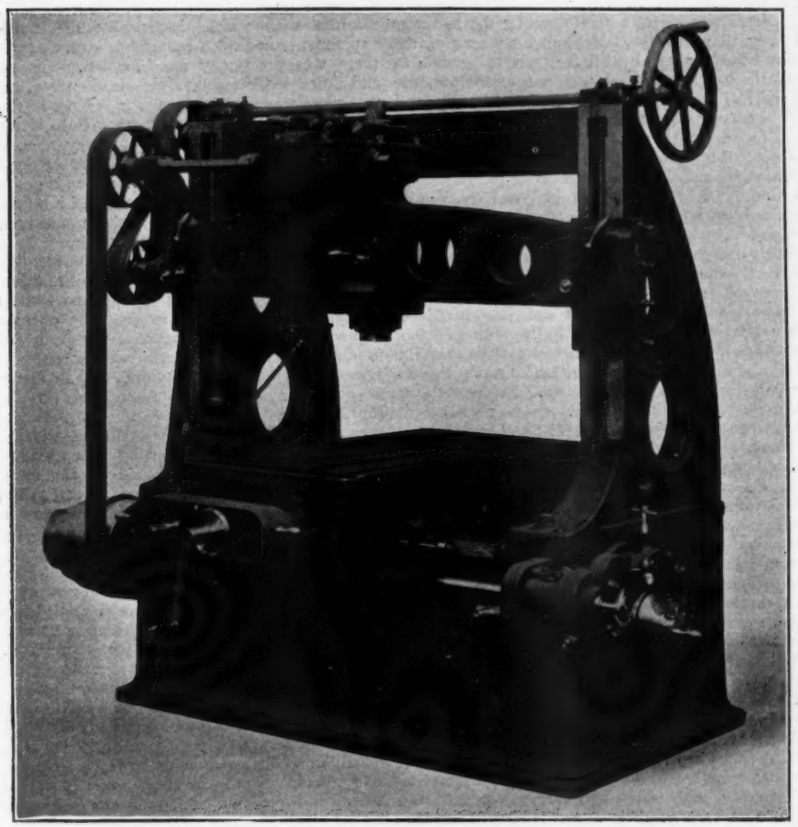


THE INSTITUTION OF MECHANICAL ENGINEERS.

An ordinary meeting of this Institution was held on Friday, the 17th ult., at the Institution of Civil Engineers, the President, Dr. W. C. Unwin, F.R.S., occupying the chair.

Hardness Tests Research.

The usual formal business having been transacted, Dr. T. E. Stanton proceeded to read the paper set down for that evening, entitled "Report of the Hardness Tests Research Committee," by Dr. T. E. Stanton and Mr. R. G. Batson. Of this paper we commence the publication on page 552.

The discussion was opened by Sir Robert Hadfield, F.R.S., who stated that in the first place he would take the opportunity of saying that the committee owed a considerable debt of gratitude to Dr. Stanton for the manner in which he had carried out his part of the work. He did not suppose that because he (Sir Robert) happened to be one of the members of the committee he would be misunderstood if he said that the research had been carried out under particularly favourable conditions, conditions which might well be imitated in other reports of the kind. A body of scientific and practical men, appointed by the council of the Institution, had met together from time to time, drawn up a programme, and carried out the work in a manner which had given important practical results. He should add that the president of the Institution had been particularly active, and, as always, had made most useful suggestions, which had greatly increased the value of the work done. Then, happily, in Dr. Stanton the right man was at hand to carry out the experiments decided upon. He felt that members as a whole would agree that there could not have been a better combination in order to obtain theoretical and practical results. He would ask whether in the working out of the experiments a special proof was not afforded of the advantage of having the National Physical Laboratory available for such work. It was more than probable that without the ready co-operation and help of the Laboratory the results would either not have been attained at all or they would have taken a longer time to secure.

Some of the results put forward in the report were entirely novel, and accordingly new to many engineers and metallurgists. For example, it was known that manganese steel, now so widely used, did not owe its wonderfully high wear-resisting properties to the inherent quality or composition of the alloy, but to certain curious characteristics which he (the speaker) had noticed many years ago, and which had also been noticed by the late M. F. Osmond, the well-known French metallurgist. Strange as it might seem, the great advantage obtained in the use of manganese steel for certain special purposes—such as the faces of crusher jaws, and the wearing parts of crushing machinery, also for tramway and railway work—did not arise directly from the composition of the steel or its treatment. Many might not understand that point. Manganese steel, as such, while untoolable, was really quite a "soft" subject, of great toughness, possessing only about 200 Brinell ball hardness. At the very moment, however, that the application of crushing or rolling produced deformation, the skin of the surface was immediately changed into quite another structure. of an entirely different and much greater hardness, passing from about 200 ball hardness into one of 300 to 500 ball hardness number. This was a very peculiar property. The hardness of manganese steel in the lathe was due to the same fact, namely, that as the material was cut it became hard, so to speak, artificially; in other words, it could not be cut without producing deformation; but the moment hardness was produced it could be machined. Only indirectly was this due to composition or heat treatment.

Sir Robert then referred to a sample of a jaw for a stone-breaking machine, exhibited on the table. The hardness of this specimen was 200 ball number all the way through. By use it had suddenly changed its composition to anything from 300 to 500 ball hardness. If the sample were tested before being put to use the hardness would be found to be uniform. Nothwithstanding its strange faculty of changing materially its composition, no change in microscopic structure could be observed. There was no change on the immediate surface that would lead anyone to suppose that the steel could show so enormous a difference, a change, so to speak, from a state of soft grey iron to a state of chilled iron. The effect was not one of temperature, only of deformation. It was for this reason that jaw faces for crushing machines made of manganese steel, when first put to work, appeared to wear no better than ordinary steel—confirming what the speaker had already said—but as soon as the surface had been glazed over by pressure, friction or otherwise, the hardness jumped up. The remarkable resistance to wear which it then possessed was of the greatest practical advantage, as many knew by experience. As the hardness wore away, another hard skin formed immediately underneath, and the process was repeated until, after many years' use, the full thickness of the wearing portion of the article disappeared. To put the explanation in another way, the material might be said to be self-hardening at natural temperatures; that was to say, without heating, unless the amount of friction or deformation set up generated a certain quantity of heat. That was hardly likely, or at any rate such influence in itself would not be great; the curious change noticed was due to pressure or deformation rather than to increase of temperature. The immediate surface affected was at first only very thin, but it gradually increased until the material offered the desired resistance to wear, and the wonderful durability noticed was obtained.

As Dr. Stanton had correctly termed it, hardness of the deformed surface was brought about, and the quality of the material, which in the first stage—the toughened condition—offered but little more resistance than ordinary steel to sliding abrasion, was changed. In other words, pressure had also to be present to bring about the change. That peculiar property removed, manganese steel would, for such particular purposes, be of little more value than ordinary steel of hard grade. He specially referred to this fact, because it was another proof of how the scientific man discovered things by accuracy of working. Dr. Stanton had known nothing of this peculiar property of manganese steel; in fact, he (the speaker) had not thought of informing him at the time when the various specimens were prepared and sent to his laboratory. As would be seen from the results given in the report, Dr. Stanton had discovered the facts for himself. This, therefore, was still another peculiarity of manganese steel added to its curious non-magnetic and other strange physical properties.

Sir Robert next referred to a diagram which he submitted as showing the increase of ball hardness produced by the tensile stretching of manganese steel, as compared with carbon and nickel steels. Another important fact was shown by the experiments recorded in Table I of the paper, namely, that hardened steel, after being slightly tempered, was positively harder than steel not so treated. Possibly this was due to some slight change in the structure of the crystals, which, owing to this slight tempering, adjusted themselves. The speaker was specially investigating this point in other directions in which this peculiar characteristic might be of service. One important conclusion to be drawn from the experiments was the little that was known of hardened material and its qualities. In this new direction the accumulation of knowledge was only just commencing. Each special firm had generally its own way of arriving at the desired qualities and of explaining them when so obtained.

In many cases, however, the conclusions were mostly empirical. It was therefore necessary that all concerned should set to work to improve knowledge in this important new field as to the quality of hardened steel. He would accordingly beg those interested to study some way of determining accurately the hardness of hardened steel. At present, after reaching what was called "glass scratching" hardness, experimenters were still much in the dark. (Glass scratching hardness corresponded to the ball hardness number of 600.)

Brinell, in his valuable papers presented to the Iron and Steel Institute many years ago, stated that he could determine up to about 800 ball hardness, or 200 points higher than that at which steel commenced to be what was called "dead hard." He would remark parenthetically that engineers owed a great debt of gratitude to this eminent Swedish metallurgist. It was entirely through his labours that so much benefit was derived to-day. For every part of an automobile, of a motor, of an aeroplane engine, and for a variety of other purposes, such as projectiles and armour plates, it was essential to employ the Brinell test. Thousands of these determinations were made every week on comparatively large articles, and in many cases where small articles were produced. In many works, indeed, there had been tens of thousands of such determinations of hardness. It was due to Brinell that to-day we were able to measure hardness, and speak of it with a marked degree of accuracy. His method, however, whilst most excellent—he could not speak too highly of it for ordinary ball hardness numbers up to about 600—was a somewhat difficult and tedious process, giving results often only approximately correct. All interested, therefore, would be greatly assisted if those making apparatus and special instruments relating to the determination of hardness would study methods of enabling hardnesses varying from 600 to 800, or even higher, to be quickly and correctly obtained. The speaker had heard of nothing higher than 780 Brinell number, and that was not with an alloy, but with a piece of plain carbon steel. Indeed, plain carbon steel seemed in some ways to be able to take a rather higher degree of hardness than special steels; he referred, of course, to extreme hardness.

Sir Robert went on to say that if the council would permit he would be very glad to offer an inducement by way of a prize, either monetary or a medal, to anyone within the Empire who could bring about an accurate way of determining hardnesses of the nature he had mentioned. The methods chiefly used at present were as follow: First (*a*) the Brinell apparatus, in which determination was effected by pressing and using hardened steel balls of different diameters, with standard pressures of 1,000, 2,000, and 3,000 kg., and up to 5,000 kg. In the speaker's own case, if it were desired to determine extreme hardness, pressures up to 5,000 kg. were used. That pressure was, of course, enormous, and it was somewhat difficult to get balls that would withstand it, but up to now this had been achieved without serious difficulty. There was another trouble, that of keeping up such an extreme pressure as 5,000 kg. It had to be borne in mind that, in trying to take such hardnesses, the material dealt with was not tough, but comparatively brittle, and cracks might supervene. It was divulging no secret to say that not many years ago his own firm believed they had obtained a magnificent way of determining the requisite hardness for the points and shoulders of projectiles. A number of these projectiles had been tried, with, apparently, wonderful results. A few weeks later, however, it was found that the whole of the projectiles were cracked. These cracks were so minute as to escape observation, and it would have been quite possible to have sent the projectiles out. Had they got into the magazine and been fired, they might have blown up the entire ship. That showed the great care needed in opening up a new line of testing. The defect was, however, noticed in time, although the cracks were very difficult to see. At the time of testing, when the pressure was put on, they were not noticed, but the pressure was there, and in a short time there was spontaneous rupture, with the undesirable results indicated.

The second method (*b*) in use was the rebound test, such as was employed in the Shore scleroscope method; also the Pellin, or French method. The third method (*c*) was the scratching apparatus, represented by the useful device invented by Professor T. Turner, of Birmingham. None were quite satisfactory or entirely met requirements in obtaining the hardness of very hard steel.

The speaker submitted for exhibition the Pellin apparatus, not very well known in England. This apparatus was useful for determining the hardness of very thin material. Neither by means of the scleroscope nor the Brinell ball was it possible to take the hardness of such material, as the pressure of the ball distorted the thin sheet too much, and the scleroscope test was of no great value in such cases. With the Pellin apparatus, however, tests of thin material were feasible. He might mention that the apparatus had been recommended to him by M. Henri le Chatelier, and the results obtained with it were exceedingly good, quite comparable with those of the Brinell and other existing methods. Sir Robert stated that he proposed to hand to the secretary his own comments, an extract from Wahlberg, and the papers contributed by Brinell to the Iron and Steel Institute. The latter really constituted the beginning of this important line of hardness investigations, and in them was much useful information as to the results of ball-hardness temperatures. In regard to comparative tests, it might, the speaker said, seem easy, when a certain Brinell test number had been attained, to translate it into a scleroscope number. One indentation, one pair of products, would give certain results, but to make a comparative table was nevertheless impracticable, and under present conditions the scleroscope results could not readily be converted into Brinell numbers. Referring to certain reports which he proposed to hand to the secretary, in order that they might be thought over more carefully, he remarked that he had carried out some scleroscope experiments to determine the hardness of various minerals, so as to get some idea of the hardness of such products as compared with metals. He had mentioned the subject to his friend Dr. Holloway, who considered the work done would be of value. It had never been presented before, and he thought it might advantageously form part of the report. From the table which he intended to submit he would take a few examples, commencing with talc—the table went up the scale to corundum. The scleroscope numbers for talc were 6 to 8, average 7; selenite, about 20; calcite, 40 to 45; fluorspar, about 50 to 60; apatite, about the same; feldspar, 80 to 90; quartz, from 72 to 111. On the cleavage face 72 was obtained with quartz, on the polished face 93, and in the case of another specimen 111. Topaz varied from 38 to 42, and corundum from 22 upwards, but in this latter case, of course, no result could be tested with accuracy. One mineral he had not tested, namely, the diamond. He had endeavoured to obtain diamonds from the people engaged in the industry, but they refused to let him have them without a guarantee that he would not split them. He hoped, however, at some future time—after the war—to accomplish this test also. In conclusion he desired to again express the great indebtedness of the Institution to Dr. Stanton for the excellence of his report.

Mr. E. H. Saniter, who was the next speaker, remarked that he had studied the report with the greatest pleasure. In describing the speaker's method of test, the report stated the diameter of the specimen, the internal diameter of the wearing ring, the speed, and the load on the test piece. That, however, did not give quite the whole of the factors, for the reason that while, in the speaker's machine, the ring was $\frac{3}{4}$ in. wide, the wearing surface in the case of Dr. Stanton's machine was only $\frac{1}{4}$ in. wide, with the result that the load on the point of contact, instead of being about twice as much, was about six times as much. It was possible, therefore, that the divergence in results, alluded to by Dr. Stanton, might have been due to the difference in pressure. He would not suggest that the one pressure was better than the other; he had no knowledge on that point; one pressure might be better for some purposes and the other for other purposes. Dr. Stanton had alluded to the shiny appearance of some of the specimens after test, regarding this as due to the re-rolling of the abraded particles, but in the case of the speaker's machine, with less load, the specimens tested showed a distinct matte surface. Dr. Stanton had very properly pointed out the importance of vibration in connection with testing machines; it was necessary to have a machine with either a constant vibration or one with no vibration at all. The machine with which the speaker had made his experiments had been brought to such a stage that there was practically no vibration. The spindle and chuck of the machine were in one piece, and the test piece was gripped simply in a hole, at the end of the spindle, by six set screws with lock nuts, by which centring could be done very accurately; the load was applied by a lever above. An egg could be placed on the top of that lever when the machine was running at 4,000 revolutions, and it would not move. In Table I of the report it would be noted that in the case of test No. 6 the Brinell hardness number was only 420; yet this test showed less wear than No. 5, of which the Brinell number was 453. That result was of exactly the same class as the speaker obtained in the case of his own experiments. His experience in regard to the wonderful wearing properties of manganese steel agreed with that of Dr. Stanton, and he concurred in attributing, as Dr. Stanton and Sir Robert Hadfield had done, these wearing properties to the surprising hardening of the surface which took place in the manner described by those speakers.

The report had also referred to the increased hardness under the Shore scleroscope after the wear test, remarking, however, that the increased hardness did not account for the reduced wear. In this connection the speaker ventured to suggest that possibly the scleroscope hardness was not the true hardness. The film might be so thin that even the scleroscope would penetrate to the soft backing, and probably the real film on the surface was much harder than that shown by the scleroscope. It had been a great pleasure, however, to Dr. Baker (who had carried out the work in connection with Mr. Saniter's former report) and to himself to observe how their results had been confirmed, and to learn from Dr. Stanton that the machine used was a valuable one for ascertaining wear.

In relation to the machine which Dr. Stanton had made for sliding friction, it was interesting to note that the surfaces were not hardened, and also that there was as great a discrepancy, or a greater, between the ordinary Brinell or Shore test and the results produced by that machine. This pointed to the fact that up to date the only way to ascertain the wearing properties of a steel was by some method of wear test. In view of the additional knowledge afforded by the report, it occurred to the speaker that it might be possible to define somewhat the properties necessary to resist wear. First of all he would put the resistance to distortion, as illustrated by the Brinell test; secondly, the hardness produced by distortion, as illustrated by the manganese steels; and, thirdly, the toughness, as shown by the shock test, such as the Charpy test. He thought it probable that a combination of these tests would be found to give indications similar to those of actual wear tests. For instance, if a piece of steel were tested with the Shore scleroscope and also with the Brinell test, and then a further scleroscope test were applied in the Brinell test depression, figures would be obtained which might be an indication of the hardening up properties under distortion. Supplemented by a shock test to ascertain the toughness of the material, these figures might yield data which would lead to further useful indications. In conclusion he would suggest that shock tests might be added to the report in connection with the other tests of the specimens dealt with.

Mr. G. A. Main spoke next. He alluded to measuring the hardness of very hard steel, as a very real difficulty experienced in the steel trade, that difficulty being that the Brinell test, so largely used for the ordinary ranges of hardness, broke down, owing to the deformation of the ball, at the higher ranges. He believed that the scleroscope or Shore test suffered from the same disadvantage; at any rate, the readings are very variable. He did not consider that the scratch test had been developed

sufficiently, principally, he supposed, on account of the fact that the indentation and other methods had been so much more convenient. Where, however, these methods failed, as in measuring the hardness of hardened steel, he thought the scratch method might be further considered. In making the suggestion he realised that use of the scratch method involved another method of testing and another scale of hardness; in other words, covering much the same ground as had been traversed, in connection with temperature scales, since the thermometer was invented. There would be a revival of the old bugbear that existed as between the F. and C. scales. How to change one of these into the other was understood, but with the different scales of hardness now in existence the interchange would scarcely be possible. It almost seemed to the speaker that the question of measuring hardness and giving a rational figure for use would never be mastered, in such a way that one piece of steel could be described as possessing twice the hardness of some other, unless the real reason for hardness were first discovered. The problem remained as difficult as in the past, and a problem over which metallurgists, as distinct from engineers, had spent much time.

Mr. G. F. Barrett was of opinion that in the manufacture of ball and roller bearings the hardness of the surface of the race was of great importance, and at the speaker's works a method of testing was in use whereby many thousands of pieces were tested daily. The method consisted in using a rod of carbon steel hardened and ground off exactly at right angles, and when that was run over the surface of the steel it was surprising to find what a small pressure was necessary to detect the slightest hardness, whether due to quenching or inequalities in the steel. This method only indicated soft, tacky and not extreme hardness, but it did so in so remarkable a way that he thought some such arrangement might be considered, provided the amount of force could be measured, because the pressure on the work was so slight. The speaker exhibited some rings, from which the delicacy of the test became apparent. He also showed a roller race which had sustained a load of 6 tons, and it was of interest to see the blistered appearance of the hard surface of the steel. The speaker raised the question as to whether the ball in the Brinell machine could be, in some way, standardised. So far as he was aware, ordinary commercial 10 mm. balls were used, and if a steel—possibly a nickel-chrome steel—could be used which could be more or less standardised, it might yield better results. [In answer to the president, Mr. Barrett stated that he would be pleased to submit to the secretary a sketch of the tool used in the method of testing to which he had referred.]

Mr. A. P. Trotter desired to offer a suggestion arising out of two observations which had been made during the discussion. The first related to the hardness of minerals, and the second to the question of a return to the scratch test. The speaker's attention had already been called to the desirability of testing fairly hard steels for gauges, and it had occurred to him that, for such small surfaces, a modification of the scratch test might be used. Members would be familiar with the scratch test scale of hardness in the text books on minerals, and many had drilled holes in glass by means of a copper rod with emery. He would suggest the use of a piece of drill steel with a flat end, say two or three hundredths of an inch in diameter, but not necessarily of a very definite hardness, in conjunction with some substance, softer, say, than corundum. His first idea in considering this point was to find a substance which could be put in as a powder, with or without water, under a definite pressure with a small flat-ended cylinder running at a definite speed, and then to discover whether the latter would or would not, after a short time, produce a perceptible depression in the surface. If the material used were too soft there would be no impression, if hard enough some impression; while by selection of material the result might be practically no impression. Another way would be to take a fairly definite abrading material and apply pressure at a certain speed. He thought that in some such way it might be possible to find a new measure, although such new measure would, unfortunately, have to be co-ordinated with existing measures of the hardness of hard steel.

Dr. Unwin referred to the extreme ingenuity of the device by which Dr. Stanton had produced a uniform sliding between the two surfaces by the use of the Oldham coupling between the ring and the piece tested. The speaker considered that there ought to be a definite relation between the Brinell hardness number and the scleroscope number. Both were indentation machines, and if there were no such relation, it would seem that there must be something in the machines or in the taking of results to account for it. Of course—taking the Brinell tests—there were certain small sources of error not allowed for in ordinary tests; he referred to the flattening of the ball and the rising of a ridge round the ball, and to the flow of the metal in producing indentation. It seemed to him that with the scleroscope there must be difficulty in getting anything like a uniform scale, seeing that a quite arbitrary form of diamond point was employed to make the indentation. Sir Robert Hadfield had suggested to the speaker that there was still great difficulty in testing very hard steels for hardness, and it was easy to see that the errors of the Brinell test would increase, since either dependence must be placed on a very small indentation or a very heavy weight must be used, in which case the indenting ball would become deformed. Personally, he had a preference for indenting by a cone and measuring the depth of indentation. It amounted to the same thing whether the depth or the diameter of the indentation were measured, and the speaker had a preference, speculative rather than practical, for the use of the cone. To avoid injury to the point, he suggested a slightly truncated cone. In conjunction with this method, an optical magnifying arrangement could be used which would give much greater delicacy than could be obtained in measuring the diameter of the Brinell indentation. Tests for very hard steels failed, for one thing, for want of delicacy, and much more delicacy of indication might be afforded by optical magnification of the movements of the cone.

Dr. T. E. Stanton then replied to the discussion. He desired to add his testimony to that of Sir Robert Hadfield as to the great help and encouragement which all who had been working on the subject had derived from the president, who, in addition to his strong interest, had himself written a good deal of the report. The speaker had been very glad to hear Mr. Saniter's remarks, and he hoped soon to see that gentleman's machine at Sheffield, in accordance with the kind invitation extended to him. Rolling abrasion tests were extremely difficult, and great credit was due to Mr. Saniter for the way in which he had perfected his method, quite the best existing method of determining resistance to rolling abrasion. The president and Sir Robert Hadfield had both referred to the relation between the Brinell hardness number and the scleroscope. He thought, however, that the diagram showed fairly well that, at any rate for the softer steels, the relation was very definite. Of course—Mr. Batson would agree with this remark—the scleroscope was not an instrument to put into the hands of a beginner; it certainly required very delicate handling to get consistent results. In conclusion he would like to put on record his indebtedness, and the indebtedness of the committee, to his colleague Mr. Batson, who had in fact carried out all the tests. The measure of success attained was therefore due to Mr. Batson, who possessed the most valuable characteristic of a research scholar—that he was never discouraged. If it had been necessary to record all the failures made in the course of the work, the report would not have been of interest to the meeting; indeed, the real value of the work was in the overcoming of failures.

Dr. Unwin then brought the proceedings to a close, stating that the next meeting would take place on Friday, December 15.

SHIPBUILDING ACTIVITY IN DENMARK.—The Copenhagen Floating Dock and Shipbuilding Company has secured a site of 70,000 sq. m., for extending the works; for this purpose the capital is being increased by 1,000,000 kroner, to 3,000,000 kronen. (1 krone = 1s. 1½d.)

VERTICAL MILLING MACHINE.

WE illustrate in the view on page 549 a vertical milling machine with duplex drive to spindle, built by Messrs. George Richards and Co., Limited, Broadheath, Manchester. The table has a wide range of movement in both directions. The duplex drive enables the spindle to be driven at fast or slow speeds, thus enabling the machine to deal with all classes of material, including aluminium alloys, and increasing its efficiency when using very small cutters. The spindle has 12 changes of speed; it is driven alternately, as desired, by worm wheel for slow speeds and by spiral gear for the fast speeds, the change from fast to slow, and *vice versa*, being instantly effected by means of a lever placed within easy reach of the operator. The machine is built of two sizes, one in which the uprights are 4 ft. 4 in. apart, and the other in which they are 6 ft. apart. In this latter, the larger size, the cross arm carrying the spindle has a vertical adjustment by hand or power to 32 in. above the table, and the spindle has a fine adjustment of ¾ in. for putting on the feed. The machine is shown fitted with a rectangular table 54 in. long and 30 in. wide, but it can be fitted with a circular one 30 in. in diameter, having self-acting circular feed. The rectangular table feeds 4 ft. in one direction and 3 ft. in the other. The countershaft has fast and loose pulleys 16 in. in diameter for a 3½-in. belt. The machine is provided with the Richards patent positive-feed motion, in which the gears are enclosed in a dust-proof box, which can be partly filled with oil, thus ensuring cleanliness and free lubrication to all working parts. The machine has 16 rates of feed, a range of eight for each drive, which can be instantly changed or reversed. The base of the machine forms a reservoir for water, which is supplied to the cutting tool by a centrifugal pump fitted to the machine.

MACHINERY EXPORTS.—The value of the exports of foreign and colonial machinery from the United Kingdom (prime movers and electrical machinery excepted) in the first nine months of this year amounted to 367,423*l.*, as compared with 516,404*l.* in the first three-quarters of 1915, and 796,009*l.* in the first three-quarters of 1914. The total of 367,423*l.* was made up as follow:—Agricultural machinery, 15,180*l.*; boilers, 287*l.*; machine tools, 22,894*l.*; mining machinery, 7,331*l.*; complete sewing machines, 8,694*l.*; parts of sewing machines, 70,669*l.*; textile machinery, 8,793*l.*; complete typewriters, 72,862*l.*; parts of typewriters, 8,871*l.*; and unenumerated machinery, 151,842*l.*

METAL PRODUCTION IN THE UNITED STATES, 1914.—The statistics of "The Mineral Resources of the United States Calendar, Year 1914," show that the United States entirely or practically rely on imports as to certain metals, some of which could be mined in the country—a state of affairs which the war will probably change. The particular statistics were compiled by Mr. Frank L. Hess, and are reprinted in the United States Geological Survey Papers I: 25 and I: 26. No cobalt ore was mined in the United States in 1914, but the imports of cobalt rose in value to 274,538 dols., though by no means large in bulk, 334,556 lb.; the figures for 1914 were 209,396 lb. and 95,735 dols. Nickel was not mined there, either, but the electrolytic refining of copper yielded 845,334 lb. of nickel (metal and sulphate). The molybdenum production has always been small, but is increasing. Although the United States are the greatest users of tin among the nations, they mined tin only in Alaska, where 157.7 tons of concentrates were gained, valued at 66,560 dols.; the value of the tin imported was nearly 33,000,000 dols., against 47,000,000 and 52,000,000 in the two preceding years. Titanium was mined as rutile, TiO_2, and as ilmenite, Fe_2TiO, the productions being 94 and 89 tons. The production of tungsten (as WO_3) was 990 tons (short tons, of 2,000 lb.), against 1,537 tons in 1913; about 580 tons of tungsten were imported. The production of uranium and vanadium had gone up considerably, 4,294 tons of dry ore yielding, in 1914, 87 tons of U_3O_8 and 22.3 grammes of radium, these figures being twice and three times as large as those of the two previous years. The antimony ore deposits are considered unsuitable for economic working; no antimony was mined in 1914, a little was produced in electrolytic refineries, but the antimony (metal and salt) imported had a value of 1,126,766 dols., which is a little higher than the figure for 1913, when the imports were only one-third in bulk. White arsenic has not been directly produced for several years, the by-production in smelters (4,670 tons in 1914) exceeding the biggest output, 49 per cent., and the imports quite satisfying the demands. Bismuth ores were produced in one mine only; some bismuth comes from the lead bullion refineries; the imports were smaller than in any year since 1904. The prices were rising, however, and the reclamation of bismuth trioxide dust from smelter fumes, at present not profitable, will probably be resumed by the Anaconda Copper Company. Selenium is furnished by the electrolytic copper refineries; the production of 1914 amounted to 22,867 lb. These refineries could also supply tellurium, which, however, has hardly any commercial value. As regards manganese, we see from Bulletin 640-C (United States Geological Survey, by D. F. Hewett) that the domestic supply of ores was almost equal to the imports in 1890, but now constitutes not more than 1 per cent. of the imports, although there are manganese mines in Maryland and Virginia, which Mr Hewett describes.

THE CARONTE VIADUCT.

CONSTRUCTED BY MESSRS. DAYDÉ ET PILLÉ, ENGINEERS, CREIL.

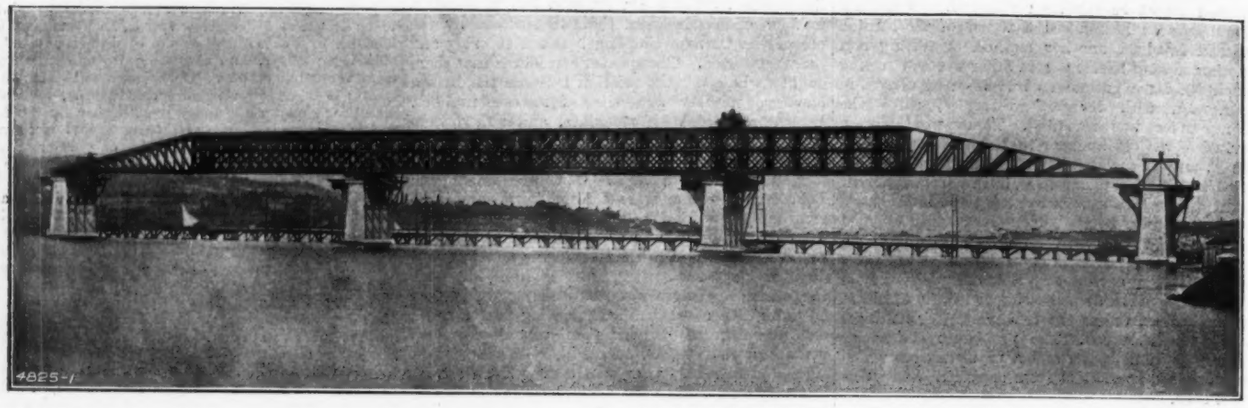


Fig. 19. Launching of a Set of Two 82.5-Metre Spans.

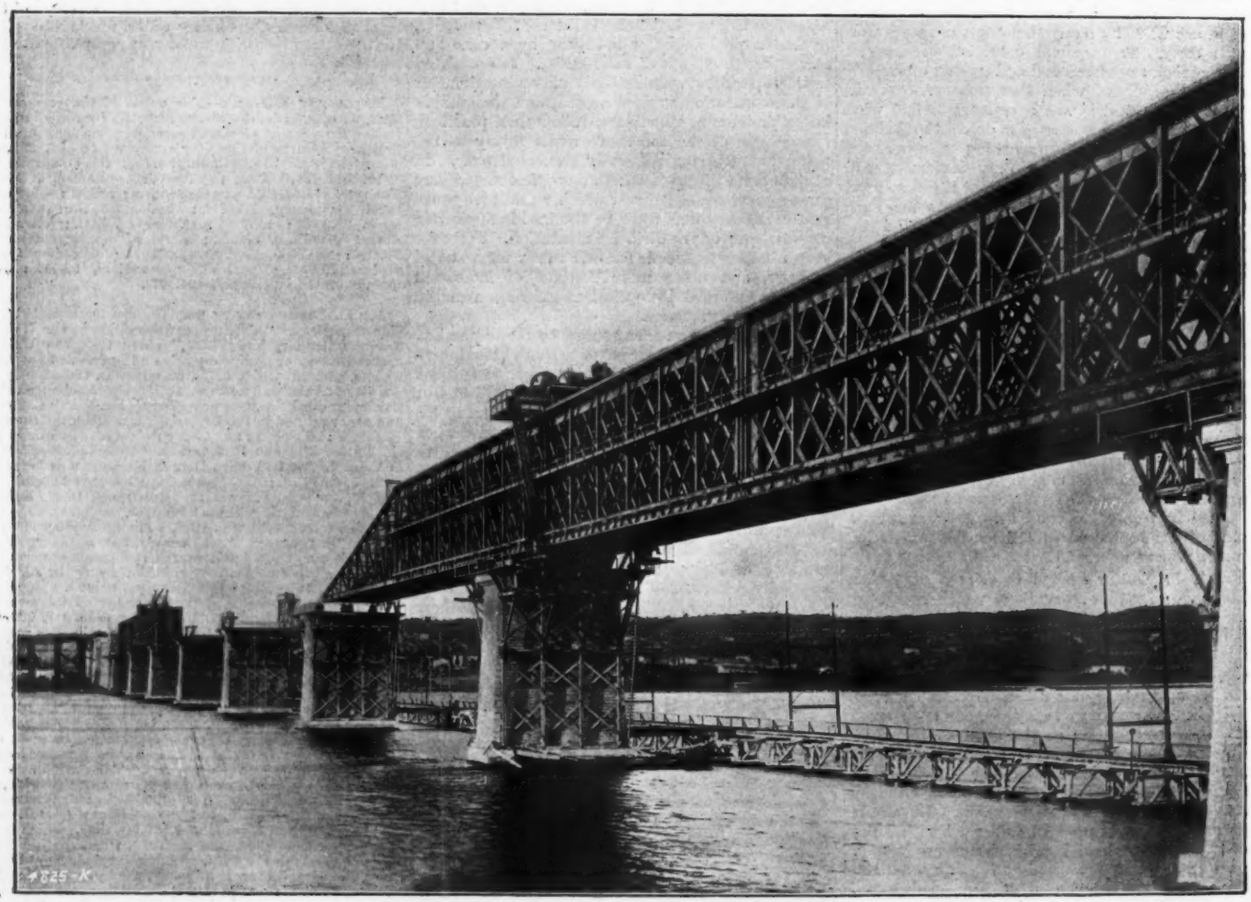


Fig. 20. Launching of a Set of Two 82.5-Metre Spans.

THE CARONTE VIADUCT.

(*Concluded from page 356.*)

The general view of the viaduct (Fig. 17, on page 358 *ante*) shows the eight 82.50 m. (270 ft. 8 in.) spans and a portion of the two 51.20 m. (168 ft.) spans. The former were built, as we have stated, by Messrs. Daydé et Pillé, and the two latter, together with the swing bridge, by Messrs. Schneider and Co. Of the 13 piers and abutments supporting the viaduct, 11 were driven by compressed air to depths varying from 15.14 to 24.58 m. (49 ft. 8 in. to 80 ft. 8 in.) below sea-level. The 51.20 m. spans, at the Miramas end of the viaduct, consist of four lattice girders 5.42 m. (17 ft. 9 in.) high and 103 m. (338 ft.) in length. The platform weighs 7,123 kg. per metre run (4,780 lb. per foot). These two smaller spans were launched without pilot extensions. They were erected on the approach to the abutment, and when erection neared completion a wooden trestle-work was mounted about midway between the abutment and the first masonry pier. When the platform rested on the latter, the trestle-work was carried between the first and second pier for completing the launching operation. The launching speed was about 5 m. (16 ft.) per hour.

A different method was followed in regard to the eight 82.50 m. spans built by Messrs. Daydé et Pillé; they were erected on the approach to the opposite abutment, in four independent sets, formed

THE CARONTE VIADUCT.

CONSTRUCTED BY MESSRS. DAYDÉ ET PILLÉ, ENGINEERS, CREIL.

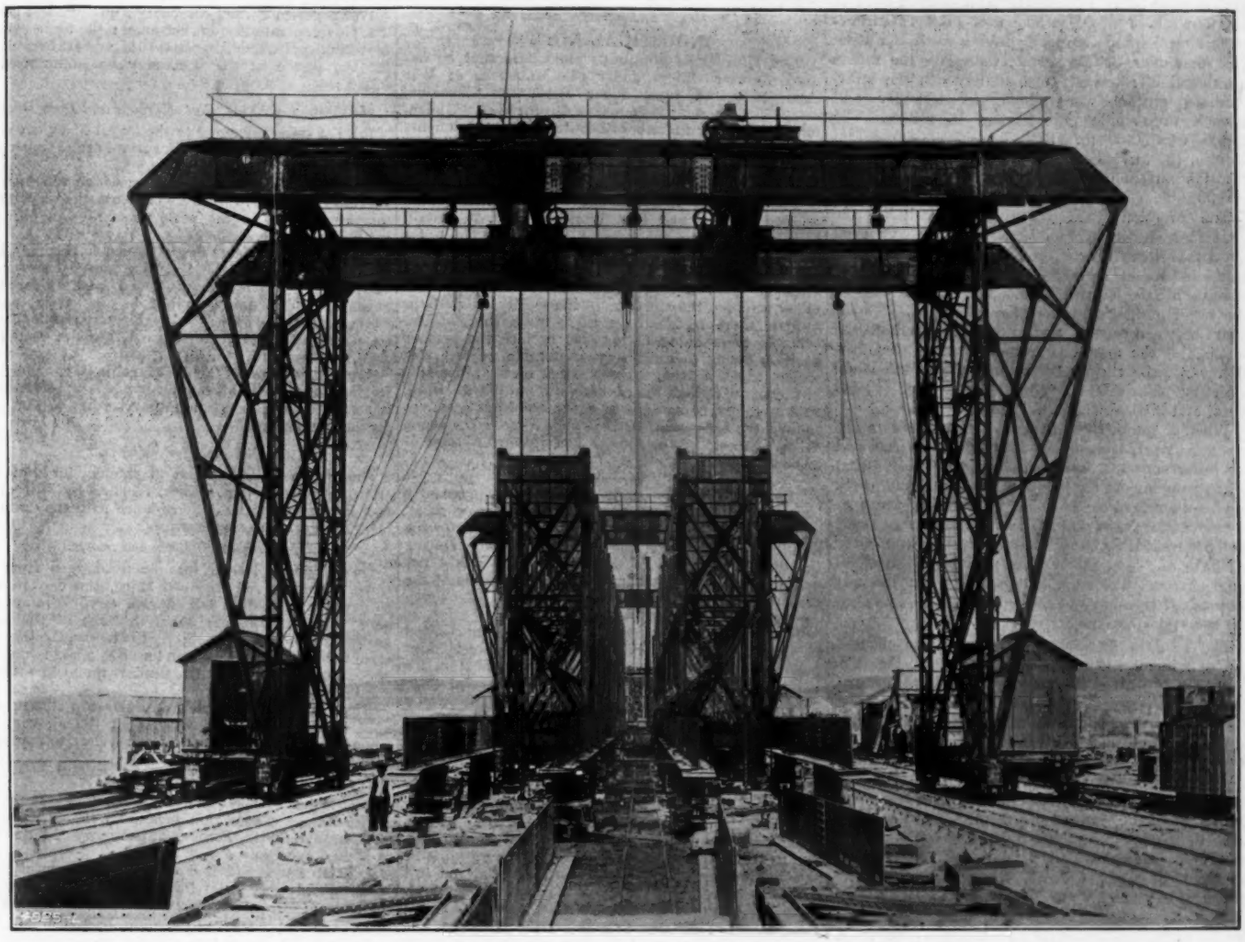


FIG. 21. ERECTION YARD.

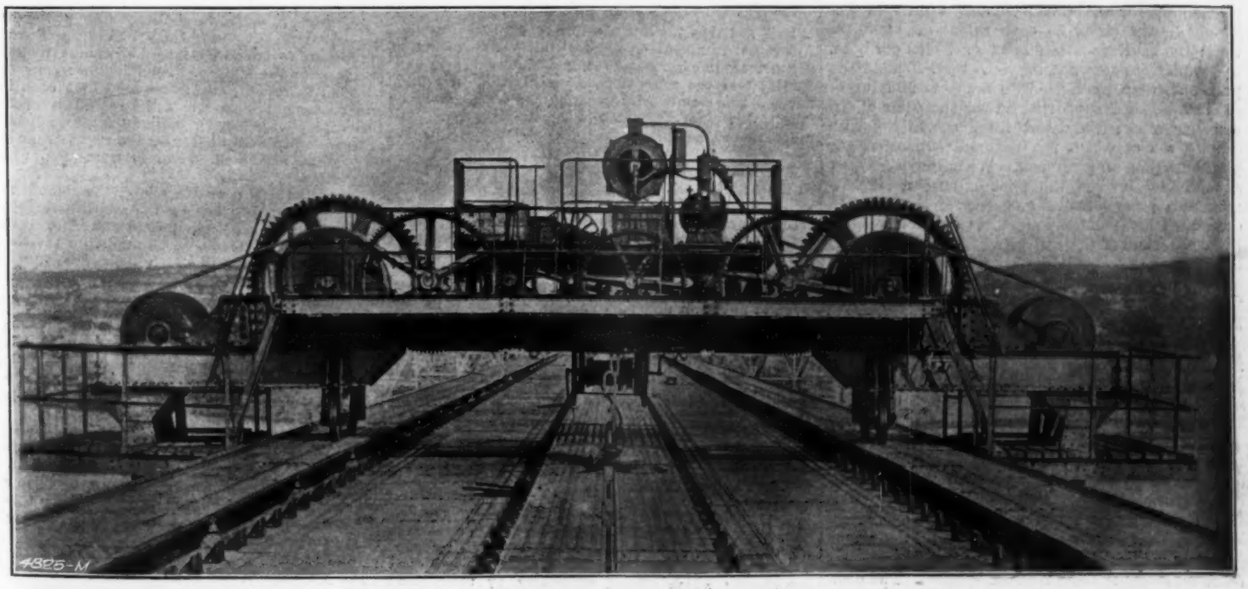


FIG. 22. WINCH FOR LAUNCHING THE 82.5-METRE SPANS.

each of two neighbouring spans, and were launched without any intermediate supporting work, but provided with pilot extensions 42.50 m. (139 ft. 6 in.) in length, as shown in the views Figs. 19 and 20, on page 552. During the launching of each of the four sets of 82.50 m. spans the platform girders rested on jointed supports having each 8 rollers. On each pier or abutment, therefore, the rollers numbered 32; the supports underneath the intermediate girders were connected together and formed one single unit having 16 rollers. The rollers were 0.50 m. (19$\frac{1}{8}$ in.) in diameter and 90 mm. (3$\frac{1}{2}$ in.) wide at the tread. The maximum reaction on each, without reckoning wind action, was 33 tons.

The erection yard on the approach to the abutment, shown in Fig. 21, page 553, was served by a travelling gantry crane. When in course of erection in the yard, the sets of two spans rested on fixed supports placed, as in the case of the roller supports in the piers, 83.20 m. (273 ft.) apart between centres, and in order to minimise the settling of the made-up ground forming the erection yard, the supports were mounted upon small masonry piers 8.50 m. (28 ft.) long, 4 m. (13 ft.) wide, and 3.50 m. (11 ft. 6 in.) deep.

When a set of two spans was completed at the erection yard, the fixed supports were replaced by roller supports similar to those above referred to, there being six having 8 rollers each and three having 16 rollers each. The forward pilot extension was then fitted on. When the set of two spans had been hauled forward in the erection yard over a length of 27 m. (88 ft. 7 in.) rendering an equal length free to the rear, the hauling operation was suspended, pending the fitting to the two spans of the rear pilot extension.

The hauling forward of the spans was effected by a winch, illustrated in the view Fig. 22, page 553, operated directly by a 10-h.p. internal combustion engine, the whole machinery being carried on a traveller which ran on the upper flange of the end girders of the spans. The hauling cables were fixed to the lower part of the end girders slightly in front of the winch. Each cable passed over a block mounted at the back of the pier to be reached, it thence returned horizontally towards the set of two spans, then, rising vertically in a line with the winch, on a return pulley fitted to the two spans, and was finally wound on the drums of the winch.

The set of two spans advanced by about 30 m. (98 ft.) in one hauling operation; on completing this, the cables were unwound, the traveller was brought back to the rear, and the hauling commenced afresh. The horizontal stress on the pier acting for the time being as a fulcrum was 77 tons; the stress on each cable was about 25 tons; the hauling speed was 12 m. (39 ft.) per hour.

The piers, as shown in the views Figs. 19 and 20 on page 552, were provided with brackets built up of steel girders and supported on the shoulders of the masonry work; they were fitted at the top with sets of rollers which received and supported the pilot extension on its arrival. When it arrived over an end pier bracket the pilot extension was dismounted progressively, and the forward action ceased when the end of the set of two spans reached the centre line of the end pier. The rollers on the bracket were relieved by jacks and supports mounted on the pier; the rollers were then removed, and the set of two spans was lowered upon the final bearings on the piers.

Each of the four sets of two spans forms a platform 165.75 m. (543 ft. 9 in.) in length, supported at each end on a pier with the interposition of a jointed expansion device and at the middle of its length on a pier, but with the interposition of a jointed anchoring device. On the pier which adjoins the swing bridge, however, the end of the first set of two 82.50 m. spans rests on an anchorage device and not on a expansion one, owing to the provision of the movable fish-plates referred to in our former article, when we described the swing span.

The masonry piers carrying the larger spans are 83.20 m. (274 ft.) apart between centres. The platform is built up of four main lattice girders, two under each track, 9.10 m. (29 ft. 10 in.) high outside angles, and 165.75 m. in total length. The two girders of each pair are 2.87 m. (9 ft. 5 in.) distant between centres, the distance between the centre lines of the two inner girders being 0.70 m. (27$\frac{1}{2}$ in.). The whole of the work of erection was carried out smoothly and without accident.

INDUSTRIAL NOTES.

The Minister of Munitions announces that he has made further Orders under the Munitions of War Acts, 1915 and 1916, under which 129 additional establishments have been declared controlled establishments. The total number of controlled establishments under the Munitions of War Acts, 1915 and 1916, is now 4,512.

The quarterly report issued by the Amalgamated Society of Steel and Iron Workers of Great Britain calls attention to the present prosperous times for the trade, which are expected to continue for a period. In the matter of high prices, the report says that although this is a very serious condition of affairs for many workers, the members of the society are perhaps a little more fortunate in their trade than others, some of them being better able to face the present position owing to their very favourable wages. The society was benefiting to some extent by the prosperity of the trade, though the executive would like to think that more was being done to strengthen their resources against the time of stress that may come. The funds at the disposal of the society had reached a total of 34,688*l.*

The third quarterly report, to September 30, recently issued by the Associated Blacksmiths' and Ironworkers' Society, stated that the membership was 13,818, or an increase of 302 over the previous quarter. During the quarter reviewed in the report there was a net gain to the funds of 1,536*l.*, the balance in hand at the close of the quarter being 43,954*l.*

The report for November issued by the United Society of Boilermakers and Iron and Steel Shipbuilders states the following:—"Our application for a 10 per cent. advance to our pieceworkers in shipyards and boiler shops is still unsettled. The increasing tendency to centralise negotiations on all questions increases the work of the general office. Apart from wages, there are national questions arising every week in which our members are vitally affected, and as most of our national questions are now negotiated in London a considerable amount of energy and time and money is unavoidably spent. This, of course, is due to the new conditions arising out of the war, but it is also true that the Government have taken a new responsibility in national industry, and their responsibility will not end with the war. We have good reason for misgivings against too much interference with customs, which have much to recommend them, even in war time, but we might as well try and stop the ocean with a broom as fight against Government control of industry, the fixing of interest on capital, and the awarding of wages for labour. . . ."

It is stated in the last monthly report issued by the Associated Ironmoulders of Scotland that there was a net increase in earnings of 761*l.*; the gross income was 2,284*l.*, and the gross expenditure 1,522*l.*, in round figures. The membership was well maintained, and the idle benefit paid, *i.e.*, 48*l.* 15*s.* 2*d.*, was the lowest in proportion to membership in the history of the Society.

The Local Government Board has issued circulars R. 106, R. 107, R. 108 and R. 111, setting forth the provisions which have been made for the use of the man-power of the country in the manner most effective for the successful prosecution of the war. They convey the decision of the Government that, except in certain special cases indicated, it will not be justifiable to grant exemption on the ground of business or employment to any man under 26 years of age who is fit for general service. The procedure to be followed in this instance and in the other instances reviewed are given in the circulars in question.

An exhibition was opened last Friday by the Manchester Gas Committee at 15, Whitworth-street, with a view to showing the value of the use of gas in the heat treatment of metals for various industrial purposes, including the manufacture of munitions. The furnaces under test included melting, heating and annealing furnaces; they are to remain available for demonstration purposes for three weeks. In opening the exhibition, the chairman of the Manchester Gas Committee, Alderman Kay, extended an invitation to all persons interested in the subject to avail themselves of the opportunity which offered of testing by their own workmen the appliances exhibited, so that they may ascertain the fitness of any individual apparatus for their needs.

The dock and harbour authorities of the kingdom held a meeting last week in London with a view to consider the offer made by Government through the Financial Secretary to the Treasury, Mr. T. M'Kinnon Wood, for settling during the period of the war the outstanding questions between the authorities and the Government concerning the charges on ships and goods. The Government offer was accepted; the terms arrived at, which apply from August 4, 1914, and are to continue for the period of the war, may be summarised as follow:—

In Respect of Ships, Port, Harbour and Dock Dues.

(*a*) For ships belonging to the Royal Navy and ships requisitioned during the war for naval use as transports, mine-sweepers, patrol ships, &c.

1. Port, harbour and dock dues, where vessels have the use of berths in open or closed docks or at other quays or jetties in the port, percentage of ordinary tariff 75 per cent.

2. Port and harbour dues in open harbours, where use is not made of the facilities specified under (*a*) above, nil; (*b*) for requisitioned and prize ships engaged in discharging and/or loading grain, sugar, timber, meat, and other goods, which are not munitions or naval or military stores, port, harbour and dock dues, 100 per cent.

Further payment of full dues for ships if carrying coal for the Navy will in all cases be made, also ships carrying munitions or naval or military stores will be paid for as "transports."

Payments for Services.

Graving dock rates and payments for tonnage, cranage, water, light, power, labour, and all other specific services to be in accordance with the ordinary tariff applicable to such services.

In Respect of Goods and Stores.

On all goods loaded into or discharged from all ships, including requisitioned ships, the Government to pay the rates, dues and charges payable in accordance with the ordinary tariff in force at the port, harbour or dock concerned; that is to say, the Government is to be put on the same terms as a large importer or exporter dealing with similar quantities under similar circumstances.

Right is reserved to the Admiralty to make reasonable deductions from payments on the above basis where they render countervailing services to a port or dock authority.

Last Saturday the executive council of the South Wales Miners' Federation received a letter from Sir H. Llewellyn Smith, Permanent Secretary of the Board of Trade, stating:—

1. That the Board had decided, after consultation with the Advisory Inter-Departmental Committee set up under the control order, to grant an immediate increase of 15 per cent. in the men's rate of wages.

2. That the Board had determined to appoint an independent auditor to ascertain, without loss of time, the facts in regard to the increase in the cost of production of coal in the South Wales coalfield.

The letter concluded as follows:—

"The Board would be glad to receive at the earliest possible date any suggestions which the Federation may desire to offer with regard to the instructions to be given to the auditor. Pending the receipt of the result of this audit, an increase of 15 per cent. in the miners' general wage rate will be paid as and from this date (December 1), but any future adjustment of wages will be contingent on the result of the audit, now to be instituted, taken in connection with all other relevant factors."

As will be seen from the above, the audit is not to be the joint audit asked by the miners (see page 503 *ante*) but one made by an independent auditor appointed by the Board of Trade. This audit, on the showing of the mine-owners, will justify their claim to a 10 per cent. reduction in wages owing to the rise in the cost of production.

The mine-owners (Monmouthshire and South Wales Coalowners' Association) met at Cardiff early in the present week to discuss the situation. At the close of the meeting they unanimously passed the following resolution, a copy of which they then forwarded to the Prime Minister and to the President of the Board of Trade:—

"That this Association, while submitting loyally to the decision of His Majesty's Government in the present crisis, desires to enter its emphatic protest against the action of the Government in again being parties to the breach by the workmen of the Conciliation Board agreement, the terms of which were settled by the Government itself last year."

The King signed last Tuesday a proclamation applying Part I of the Munitions of War Act to the difference existing between the employers and the cardroom and blowing-room operatives of the Lancashire cotton

mills. The result of this measure is to render illegal a lock-out or a strike due to a trade dispute, unless the difference has been put before the Board of Trade and a period of 21 days has elapsed since the date of the report, and unless the point in dispute has not during that time been referred by the Board of Trade for settlement. It concerns a dispute which had arisen in the Lancashire cotton trade; strike notices which had been handed in were to have expired at the end of the current week.

We are informed that Mr J. H. Thomas, M.P., has been elected general secretary of the National Union of Railwaymen, in succession to Mr. J. E. Williams. The figures were 107,333 votes for Mr. Thomas and 32,732 for Mr. Bellamy.

Commenting upon some criticisms of German plant by Mr. Bernard Price, engineer of the Victoria Falls Power Company, in his inaugural address to the South African Institution of Engineers, as given on page 482 *ante*, the *British Westinghouse Gazette* says, according to the *Sheffield Daily Telegraph*:—

"We have now obtained a copy of the proceedings of the institution above referred to, and supplement the general remarks upon which we commented by a detailed statement of the repair work which had to be undertaken on the plant supplied by the A.E.G. and by Siemens-Schuckert. Our readers will agree that these two leading German firms have little to be proud of in the record, and that their reputation, as it existed when this plant was installed, of being ahead of English firms where large H.T. machinery was in question must be considerably discounted.

"As a nation we have been remarkably ready to take others at their own valuation, and as mundane values are comparative only, this has led as a necessary corollary to the self-depreciation which is being deplored in the daily press.

"It is difficult to preserve a mean in these matters, but one can see that the inflated value that the Germans have put on their character, education, &c., has led them to under-estimate the power of other nations, and undue modesty may be not less dangerous."

THE GREEK FLEET.—Since the war with Turkey the Greek fleet has been improved by the purchase in July, 1914, of two fairly good ironclads (the Mississippi and the Idaho from the United States), which have been renamed the Kilkis and Lemnos. Some new torpedo craft have also been completed. A light cruiser named the Helli, formerly the Chinese Fei Hung, has also been purchased from the New York Shipbuilding Company. At the outbreak of the present European war Greece had several ships under construction in British, German, French, and other yards; but in some of these the orders originally given have lapsed. For instance, the battle-cruiser Salamis, building at the Vulcan yard, Stettin, has been seized by the Germans. The following is a nominal list of the Greek fleet:—Kilkis, battleship, 13,000 tons displacement; Lemnos, battleship, 13,000 tons displacement; Hydra, battleship, 4,808 tons displacement; Psara, battleship, 4,808 tons displacement; Spetsai, battleship, 4,808 tons displacement; Averoff, armoured cruiser, 9,956 tons displacement; Helli, light cruiser, 2,600 tons displacement; and 21 submarines and minor vessels. Five of the submarines carry two 14-in. torpedo tubes and two others five 18-in. torpedo tubes.

DIESEL ENGINE USERS' ASSOCIATION.—At the November meeting of the Diesel Engine Users' Association the president (Mr. Geoffrey Porter) announced that the committee's report on "Air Compressor Explosions and Troubles," with their recommendations on the subject, had been finally revised, and that it would be printed and circulated to the members and subscribers. The honorary secretary gave particulars concerning several types of distance thermometers for use on air compressors which he had collected from instrument makers, with information concerning cost of installation. Mr. George B. Vickers then read a paper on "Piston and Small End Lubrication in Diesel Engines," which dealt with the various classes of lubricants and the different methods of applying them. A discussion followed, in the course of which Mr. W. Fennell gave information concerning inquiries he had made in regard to the possible use of deflocculated graphite and special graphite preparations for the lubrication of Diesel engine cylinders. Apparently this form of lubrication had not been tried in many cases, and the information he received from a few quarters was not sufficient to justify his making any experiments with it on the engines under his control. He also referred to the increased sulphur contents of certain fuel oils which were now being used; it was found that these reacted on the lubricating oil, especially if this was compounded with vegetable oils, causing a sticky deposit, analogous to vulcanised bitumen, which destroyed the lubricating properties of the oil. He considered it important that for cylinder lubrication a pure mineral oil only should be made use of. The real difficulty in lubricating a Diesel engine cylinder was the absence of an oil which would stand the temperature of burning gases. He expressed the opinion that the most successful Diesel engine of the future would have a crosshead. He also strongly advocated separate lubricators for each point to be lubricated.

FATAL EXPLOSION OF A DIGESTER.

THE Board of Trade has issued a report of a preliminary inquiry under the Boiler Explosions Acts, 1882 and 1890, with regard to the explosion of a digester which occurred on March 30 last, at the works of Mr. Daniel Fletcher, animal food maker, Wildriggs, near Penrith. The explosion resulted in the death of two persons and severe injuries to several others.

The report states that the digester, which was placed vertically on cement blocks, was cylindrical, and formed of five iron plates, ⅜-in. in thickness, connected by single-riveted lap joints, the ends being dished plates, $\frac{7}{16}$ in. thickness. It was 4 ft. in diameter, with a vertical height of 4 ft., the total height over the dished ends being about 5 ft. An opening, 16¾ in. in diameter, was provided on top for charging the vessel, and a seating, 8 in. in height, was riveted round the opening, a spigoted cover being secured by four bolts 1 in. in diameter. A D-shaped opening for discharging the contents was fitted with a cast-iron frame which was riveted to the shell. The door for this opening, which was also cast-iron, 1¼ in. in thickness, spigoted and strongly ribbed, and provided with a handle on each side and a ring-bolt on top, was held in place by a strong-back, the ends of which were taken by slotted wrought-iron pillars which were inserted in square holes in sockets on the frame, and secured by cotters. The pressure of the door against the frame was maintained by a central bolt, 1¼ in. in diameter, screwed through the strong-back. The metal around the sockets for the pillars was from ⅜ to ½ in. in thickness. The cotters, which were tapered from 1½ to ¾ in., were 5 in. in length, and about ¾ in. in thickness. The lower edge of the discharge door opening was in line with a perforated false bottom, underneath which a perforated steam pipe was placed. Steam for heating purposes was obtained from an adjacent vertical boiler by means of a steam pipe 2 in. in diameter, a stop-valve being provided on the pipe, and a check valve, unadjustable, on the digester. Two small seatings were riveted to the top end, but they were blank flanged. A glass water-gauge, steam-pressure gauge, outlet cock on the side, and a discharge cock on the bottom, with a pipe connection to a tank adjoining, were provided.

The digester, which was obtained from Messrs. G. and A. E. Slingsby, machinery merchants, Hull, in February, 1915, and had been previously in use, was traced to a sale of plant at Westhoughton, but the name of the maker was not known. It had been in use at Wildriggs about 11 months, and was inspected on January 27, 1915, by a surveyor to the British Engine, Boiler and Electrical Insurance Company, Limited, Manchester, at the premises of Messrs. Slingsby, on behalf of Mr. D. Fletcher, prior to purchase. The vessel was not again examined after that date by the insurance company and was not insured.

The vessel was used by Mr. Fletcher in connection with his business of horse slaughtering and the preparation of animal foods. It was charged from the top opening, the discharge door being meanwhile secured in place, and when the top door was bolted in position steam was admitted by opening the intermediate stop valve on the steam pipe. A full charge occupied about three-quarters of the internal capacity, and the time taken to carry out the process was usually about five hours.

The vertical boiler which supplied steam was worked at about 30 lb. on the square inch, and the safety valve blew off at 60 lb., the digester being worked at a maximum pressure of 16 lb. per square inch. No safety valve, adjusted to blow-off at that pressure, was provided on the digester, and consequently a lower pressure than that carried on the vertical boiler could only be maintained by manipulating the steam inlet valve.

On Thursday, March 30, the digester was charged about 11 a.m., and steam was admitted about 12.15 p.m., the pressure on the boiler at that time being about 30 lb. per square inch. About half-an-hour afterwards the pressure gauge on the digester showed 5 lb. pressure, and about 15 minutes later the pressure was 15 lb. It was stated that the pressure remained at 15 lb. up to 2.30 p.m., and as far as could be ascertained the pressure on the boiler varied from 30 to 40 lb. Mr. Fletcher and his man were meanwhile working in the slaughter-house adjoining, and hearing a report they returned to the boiler-house and found that some of the packing, which formed the jointing material of the discharge door, had been blown out from the left-hand side, and steam and fat were escaping. The steam inlet valve was at once closed, and the pressure on the digester gauge was then observed to be 10 lb. An old bag was placed over the leakage, which was allowed to escape into a drain, and both men returned to their work in the slaughter-house. About 3 p.m. the gauge showed there was no pressure in the vessel, and the discharge door was then removed, and the jointing material having been repaired, the door was again fitted into position, being secured as usual by screwing up the central bolt on the strong-back. At 3.10 p.m. the steam inlet valve was again opened about a quarter-turn of the wheel, and about 2 minutes later it was noticed by Mr. Fletcher that the pressure in the digester was from 4 to 5 lb., and turning round to the boiler he observed that the pressure there was 30 lb. He then stooped to examine the boiler fire, and on closing the fire door and resuming an upright position he heard a sound of escaping steam, and was struck on the right side with what was believed to be one of the projecting handles of the discharge door. He was then about 2½ ft. from the digester. The house was filled with steam and the floor covered with part of the contents of the digester. Mr. Fletcher's assistant, a man named I'Anson, was about 6 to 7 ft. away from the digester door, and in a direct line with it; he was struck by the door and the projected contents, and died two days afterwards. At the moment, Mr. Fletcher was examining the boiler fire, and his assistant's wife, Mrs. I'Anson, appeared at the door of the boiler house, with her little daughter, aged 20 months, in her arms, and accompanied by another child aged eight years. When the explosion occurred the youngest child fell on the floor, sustaining serious injuries from which she died the same night, while the mother and the other child were severely injured.

The explosion was caused by the fracture of the left-hand cast-iron socket on the discharge door frame, the cotter which held the strong-back pillar in place being thus set free, and the door was deprived of its support.

In his report to Mr. Boyle, the engineer surveyor-in-chief to the Board of Trade, Mr. McGregor, the surveyor who examined the digester after the explosion, states that he examined the metal of the socket, where fractured, and observed that the upper part in line with the outer edge of the cotter had been previously fractured, and was somewhat porous. The other fractures appeared clean and of sound metal. The spanner used for putting pressure upon the door by means of the central bolt in the strong-back was of substantial proportions and had a leverage of 2 ft. It was clear that the cast-iron metal of the sockets would be subjected to stresses due to the load put upon the door in that way. The cotters were an easy fit, and it was definitely stated that they had not been hammered in place at any time, which action would have tended to fracture the cast-iron material. The insurance company's surveyor stated that when he examined the digester at Hull, he carefully scraped the sockets at that part, but found no trace of any defect. Any trouble with leakage at the door would, however, promote an endeavour to make the door tight by putting on as much external pressure as possible, and the stress on the material due to the external pressure would be additional to the stress resulting from the internal pressure on the door. Further, the absence of a reducing valve on the steam pipe between the stop valve and the digester, and a safety valve of sufficient area on the digester, made it possible for the pressure in the digester to be the same as in the boiler, and in considering the possible stresses on the material this fact cannot be overlooked. It seems clear that the socket first failed at the porous part, where also the sectional area appeared least, and its strength would thereby be reduced, as the fracture allowed a leverage on the adjoining parts. It also appeared from the evidence that the new fractures had started when the leakage at the left hand side of the door took place prior to the explosion.

The fittings connected with the digester, steam and discharge pipes, steam stop valves and discharge cocks, pressure gauge, &c., appeared to be of substantial and good quality, and it was apparent that well-intended efforts had been made to ensure safety in working the vessel. These efforts, however, might have been better directed and essential fittings provided; also, it seemed possible, that the earlier fracture in the socket might have been discovered if the vessel had been under the periodic inspection of outside competent persons.

In his observations on the surveyor's report, Mr. Boyle points out that the explosion is the more regrettable in that it caused the death of two persons as well as injuries to several others, and he concludes the report as follows:—

"The owner, who was not a competent man, seems to have exercised a certain amount of care by having the digester examined by a competent authority before he bought it, but, unfortunately, he did not have it properly fitted, so that an undue pressure could not arise within the apparatus, nor keep it under the proper periodic inspection of a competent authority.

"The immediate cause of the failure was due, however, to the fracture of a defective cast-iron socket which helped to retain the lower door in place."

THE LATE MR. JAMES KIMBER.—We regret to have to announce the death, which occurred on the 1st inst., of Mr. James Kimber, who was for many years chief engineer to the municipality of Calcutta. Mr. Kimber was 84 years of age at the time of his decease, and practically the whole of his industrial life was spent in civil engineering work in India. He qualified himself for this work at the Applied Sciences Department, King's College, London, from 1849 to 1852, and after several years spent in London and the provinces as a civil engineer, naval architect and consulting engineer, he entered, in 1859, the service of the Madras Irrigation and Canal Company, leaving for India in the early months of 1860, where he acted as executive engineer in the carrying out of a large number of irrigation, canal and other works, most of which were planned by him. Mr. Kimber became a member of the Institution of Civil Engineers in 1875.

RESTRICTIONS ON MANUFACTURE AND SALE OF ALUMINIUM.—The following Order is issued by the Minister of Munitions:—In pursuance of the powers conferred on him by Regulation 30A of the Defence of the Realm (Consolidation) Regulations, 1914, the Minister of Munitions hereby orders that the war material to which the Regulation applies shall include war material of the following classes and descriptions, namely: aluminium and alloys of aluminium, unwrought and partly wrought, including ingots, notched bars, slabs, billets, bars, rods, tubes, wire, strand, cable, plates, sheets, circles, strip. Aluminium scrap and swarf, aluminium alloy scrap and swarf, remelted aluminium scrap and remelted aluminium alloy scrap and swarf. Granulated aluminium, aluminium powder, "bronze," "flake" and "flitter." The Order, dated July 21, 1916, published in the *London Gazette* of July 28, 1916, relating to aluminium and alloys of aluminium therein mentioned is hereby cancelled. All applications for a permit in connection with the above Order should be addressed to the Director of Materials, Ministry of Munitions, Armament Buildings, Whitehall Place, S.W.

REPORT OF THE HARDNESS TESTS RESEARCH COMMITTEE.*

The committee was appointed in 1914 "to report on a Hardness Test for Hardened Journals and Pins," and its membership now stands as follow :—

W. Cawthorne Unwin, LL.D., F.R.S., chairman; Archibald Barr, LL.D., D.Sc.; Sir Robert A. Hadfield, D.Sc., D.Met., F.R.S.; Captain H. Riall Sankey, C.B., R.E., ret.; T. E. Stanton, D.Sc., F.R.S.; and A. E. H. Tutton, D.Sc., F.R.S.

The committee originated in some letters from the Mirrlees Watson Company to the late Mr. Leslie Robertson, the secretary of the Engineering Standards Committee, who suggested that the question was one suitable for investigation by a research committee of the Institution. The Mirrlees Watson Company wrote that "they had found difficulty in fixing a standard of hardness—for instance, in bearings where shafts or pins work at high speeds under heavy loads."

The committee has held several meetings, and has corresponded with some manufacturers and others who were likely to have adopted some method of testing hardness.

A memorandum was prepared by the chairman (Appendix I), on such methods of testing hardness as were known to have been used. It appeared that for ductile materials an indentation test (Brinell or Shore scleroscope) was largely used, and was found to give useful information. Both these methods appeared less satisfactory for very hard materials, such as those indicated in the reference to the committee. Further, it had been shown by Mr. Saniter that resistance to wear, as in the case of a pin or journal, did not directly depend on the hardness as measured by the indentation test.

The question of the property of materials which ensures resistance to wear on rolling or sliding surfaces appeared to be strictly within the reference to the committee. It was therefore decided that experiments on resistance to wear, and especially in the case of dry surfaces, should be made at the National Physical Laboratory. Dr. Stanton designed more than one form of testing machine for this purpose, and carried out the researches, of which an account is given in the paper which forms part of this report. Brinell and scleroscope tests were made at the same time, so that a comparison could be made between the resistance to wear and the ordinary indentation measure of hardness. The form of testing machine designed by Dr. Stanton, in which there is a definite sliding between dry revolving surfaces, seems likely to be of considerable value in solving the precise question put forward by the Mirrlees Watson Company.

The committee is much indebted to Sir Robert Hadfield for supplying the materials on which Dr. Stanton's tests were made; also to Mr. R. G. Batson, of the National Physical Laboratory, to whose care in making the tests the success of the research was due. The Research Council of the Board of Education have made a grant of 100*l.* supplementing that from the Institution.

Report on Experiments made at the National Physical Laboratory by Dr. T. E. Stanton and Mr. R. G. Batson.

A description of the nature of some of the better known of the various tests which have been devised for obtaining the relative resistance of materials to surface deformation, to all of which the term "hardness tests" is sometimes loosely applied, is given in Appendix I by the chairman of the committee. A preliminary examination of these methods shows that each of them falls into one or the other of two distinct categories. These are :—

(1) Abrasion or scratch tests, in which particles of the material whose "hardness" is to be determined are torn away from its surface by sliding contact with some other substance, whose corresponding resistance is so high that its surface remains unimpaired by the action. (2) Indentation tests, in which the surface of the material under test is permanently distorted by the pressure of a hard steel ball, cone, or knife edge.

If each of these methods were a measure of the same definite property of the material which is as characteristic of it as, say, its elasticity, it is evident that the ratio of the results of any two of the methods would be the same for every material tested. Comparisons between the results of these various tests have formed the subject of several researches which have been published during recent years. The general conclusions, as summarised by Professor Turner in his paper on "Hardness,"† read at the Iron and Steel Institute meeting of 1909, appear to be that, although an approximate agreement may seem to exist between the various methods when applied to the case of relatively pure metals in their cast or normal state, yet when the resistance to deformation is due to tempering or to mechanical treatment no comparison is possible.

That this should be so would seem to follow from the consideration that the resistance which any so-called hardness test is supposed to measure is that which the body under test exerts against a complex distribution of stress over its surface which has partially deformed or disintegrated it, and it is evident that its value will depend, not on the stress constants of the material such as its yield-point, ultimate tensile and shear stresses, but on intermediate stresses, the precise nature and distribution of which are unknown and whose ratio to the stress constants may not be constant for the same method. If, therefore, such resistance, without qualification, be defined as the hardness of the material in its broadest sense, it is clear that, as pointed out in the memorandum to the committee communicated from the members of Sir Robert Hadfield's laboratory (Appendix II), hardness is no more a definite quality of a material than is the strength of a piece of steel of definite dimensions. In the latter case, if the nature, amount and distribution of the stress are known, its resistance has a definite value which can be calculated. The only difference between this case and that of the hardness test is that, since in the determination of hardness there is no possibility of estimating the stress magnitude and distribution, we are driven more to direct observation of the consequences of such distribution than to a calculation of these consequences from the known characteristics of the material. Mechanical phenomena of this kind are familiar to engineers under other aspects, such as in the cases of the resistance of ships and aircraft to propulsion; but whereas in these latter cases the problem is to determine the resultant force exerted by the unknown pressure distribution, in the present case, as in the corresponding one of the resistance of materials to impact, the unknown quantity is the ultimate resistance of the material to the unknown stress distribution. In all the cases, however, the practical method of solution is an experimental one, and consists of setting up a similar, or nearly similar, state of tests on a specimen of the material whose behaviour is under investigation and noting its effects.

It cannot, however, be said that modern engineering practice is entirely in accordance with the views laid down above, although the development of what are called "wear" tests in recent years is an indication that it is coming to be recognised that the results obtained in the relatively simple cases of stress distribution in the indentation test or the scratch test are not applicable to those in which the action is a combination of the two effects of normal pressure and sliding. For example, there are wear tests for measuring the particular form of disintegration which takes place on the surface of steel rails due to the rolling abrasion of heavily loaded wheels. The characteristics of this kind of wear are the extremely small amount of the relative movement between rail and wheel and the high intensity of the compressive stress at the line of contact. On the other hand, there are wear tests of lubricated surfaces in which the pressure is relatively small and the rate of slipping large.

Notwithstanding this development, there seems to be no doubt that with many engineers it is still customary to regard the hardness as determined by an indentation test as a definite property of material, and as a measure of the resistance of the material to wear of any possible kind that is likely to be experienced in its use. In the face of this practice it appears to be of importance to determine under what circumstances the custom here referred to may be flagrantly misleading, or merely a rough guide which is better than no guide at all. As pointed out in Sir Robert Hadfield's memorandum, the use of an indentation test in the case of manganese steel rails is highly misleading; but, on the other hand, in Mr. Saniter's wear tests of ordinary carbon steels the correspondence between the results of the indentation and wear tests was fairly close.

On looking into the available evidence it appeared that the ground hitherto covered was not sufficient to enable any broad generalisation to be attempted, and the committee therefore decided, as a preliminary research, that a comparison should be made of the results of both hardness tests and wear tests of materials whose composition and thermal and mechanical conditions of production extended over a wide range. A series of experiments for this purpose were accordingly undertaken at the National Physical Laboratory.

On consideration of the method of wear test to be adopted, the use of the machine previously constructed in the laboratory for wear tests under rolling abrasion suggested itself. In this machine the specimen is in the form of a disc 1 in. diameter and about ¼ in. thick, which is placed between three hardened steel rollers as indicated in the sketch (Fig. 1), each roller being capable of independent rotation in a practically frictionless bearing. The upper roller is loaded with a weight, W, and its axis is also free to move in the vertical direction, so that when it is rotated motion is communicated to the lower ones by the rolling friction of the ring. By making the ring solid and the load considerable, the machine is used for wear tests under rolling abrasion, or by making the ring hollow and using comparatively small values of W the test becomes a fatigue test under alternating bending stresses.* Several preliminary sets of tests were made in this machine, and the results were considered fairly satisfactory; but it was felt that the machine could not be recommended for general workshop use owing to the complication of working parts and the extreme care needed to prevent slipping of the steel rollers as the test proceeded and the specimen became worn. It was decided, therefore, to make use of some simpler form of rolling abrasion test, and as a Wöhler fatigue testing-machine was available which with slight alterations could be adapted for wear tests by the method used by Mr. Saniter,† the necessary modifications were put in hand.

In this method the specimen is fixed in a chuck revolving at a high speed and carries a hardened steel ring (of internal diameter about twice that of the specimen), to which is attached a dead load, and wear takes place due to the rolling of the steel ring on the surface of the specimen (Fig. 2). In Mr. Saniter's machine the diameter of the specimen was ½ in., the internal diameter of the wearing ring was 1 in., the speed was 4,000 revolutions per minute, and the load 205 lb. In the fatigue testing-machine adapted for the present tests the speed was 2,200 revolutions per minute, the diameter of the specimen was 1 in., and that of the ring 1½ in. The load was 410 lb. The wear was taken as the reduction in diameter in ten-thousandths of an inch after 200,000 revolutions of the specimen. As it was considered desirable to have a quantity to represent the resistance to wear, this was taken to be the reciprocal of the above values multiplied by 1,000.

The materials used for the tests consisted of six differently heat-treated specimens of nickel-chromium steel

Fig. 1. METHOD OF WEAR TEST BY ROLLING ABRASION

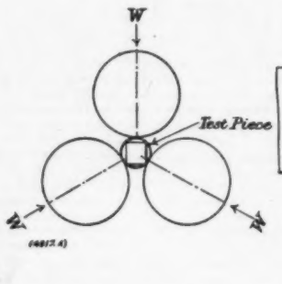
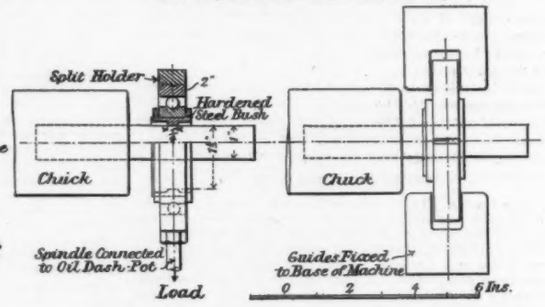


Fig. 2. WEAR TEST BY THE SANITER METHOD. (USING HOFFMANN BALL-BEARING)



containing 0.7 per cent. carbon and two samples of manganese steel, kindly supplied by Sir Robert Hadfield. On analysis the composition of these steels was found to be :—

	C.	Si.	Mn.	Cr.	Ni.
Hardened steel ..	0.7	—	—	2.0	2.5
Manganese steel..	1.36	0.36	13.10	—	—

The results of the rolling abrasion tests on these specimens are given in Table I, page 558, in which are also tabulated the particulars of the heat treatment, supplied by Sir Robert Hadfield, together with Brinell hardness tests and scleroscope tests of the surfaces before and after wear, made at the National Physical Laboratory.

For convenience of comparison the results of the rolling abrasion tests and the ball hardness tests on the original surfaces are also plotted in Fig. 3 (on the opposite page) in which the ordinates are the values of the wear as defined above and the abscissæ the corresponding values of the ball hardness test, determined in the following manner :—

The ball, 10 mm. diameter, and the specimen under test were placed between the compression-plates of a Wickstead testing-machine, and the load run on to 3,000 kilos. (W), and allowed to remain at this value for 30 seconds.

The diameter of the indentation was then measured in a micrometer microscope, and the area of the indentation was calculated from the formula :—

$$A = 2\pi (R^2 - \sqrt{R^4 - r^2 R^2}),$$

where R = radius of ball in mm. and r = mean radius of indentation in mm.

The hardness number was then take as the value of $\frac{W}{A}$.

From inspection of Fig. 3 (on the opposite page) it will be seen that the plotted points for the hardened steels lie fairly well about the straight line shown, and the results may be taken as an indication that for the same material the resistance to rolling abrasion is roughly proportional to the ball hardness number. This is in agreement with Mr. Saniter's experience with the same method of test as shown in Fig. 4 (on the opposite page), in which his results for a 0.7 per cent. carbon steel heat-treated in various ways are plotted. The comparison, however, is not a safe one, as cases frequently occur in which a considerable departure is found from this approximate relation. The

* Paper read before the Institution of Mechanical Engineers, November 17, 1916.

† See Engineering, vol. lxxxvii, page 835.

* Journal, Iron and Steel Institute, 1908, No. 1, pp. 54–70: Engineering, vol. lxxxv, pages 669, 697.

† Journal, Iron and Steel Institute, 1908, No. 3, pp. 73–80: Engineering, vol. lxxxvi, pages 453, 493.

extremely high value of the ratio of the rolling abrasion resistance to ball hardness number in the case of the manganese steels confirms existing knowledge of the properties of these steels, and is also in agreement with the results of Mr. Saniter's tests. As illustrating the important fact brought out in Sir Robert Hadfield's memorandum that the resistance to rolling abrasion of manganese steels is the resistance to deformation of already deformed manganese steel, which is known to formed material, and that, as pointed out in Sir Robert Hadfield's memorandum (Appendix II), this resistance will depend on the amount of the deformation produced, and has little relation to the material in its unstrained condition. As regards the value of the method, it was considered that as a means of predicting

Fig. 3. WEAR TEST ON SIR ROBERT HADFIELD'S SPECIMENS, BY THE SANITER METHOD

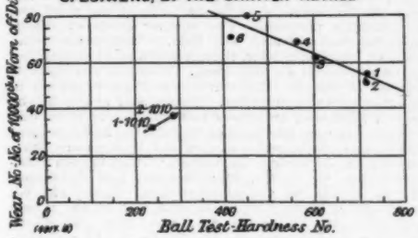
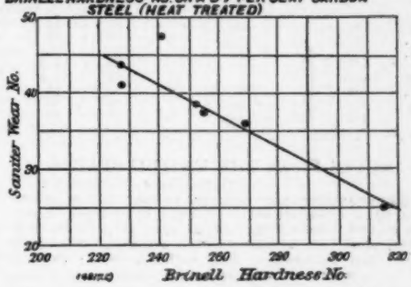
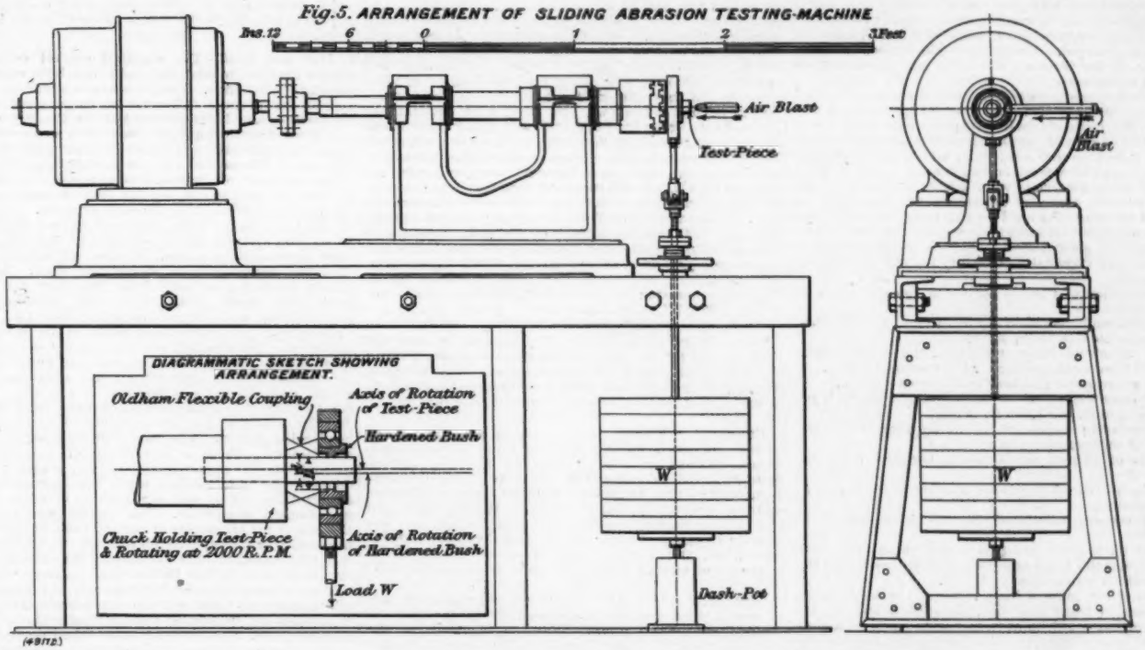


Fig. 4. COMPARISON OF SANITER WEAR No. AND BRINELL HARDNESS No. ON A 0·7 PER CENT CARBON STEEL (HEAT TREATED)



of the rolling abrasion test, there appeared to be some probability that although its results were applicable to cases of wear due to high pressure and very small relative motion, they might not be applicable to cases of the wear of surfaces in which the pressure is relatively small and the amount of relative movement is large. This appears from the consideration that in the latter case no permanent deformation corresponding to the yield-point is reached over the surface exposed to wear, but that by the relative sliding small particles are bodily detached without permanently distorting the surrounding particles. This is the case of the wear of workshop gauges, hardened steel pins and collars, &c. It was decided, therefore, as the next step, to attempt to devise some form of wear test which would apply to cases in which the relative movement of the surfaces was considerable. A system of toothed gearing connecting the abrading ring and the specimen first suggested itself, but on going into the design the mechanical arrangements were so complicated and costly that the machine was not put in hand. Finally, the idea occurred of connecting the abrading ring (internal diameter D) to the chuck by means of an Oldham coupling, so that both ring and specimen (diameter d) should complete a revolution in the same time, the line of contact remaining fixed relative to the machine. In this way if π D inches of the surface of the ring and πd inches of the surface of the specimen passed the line of contact per revolution,

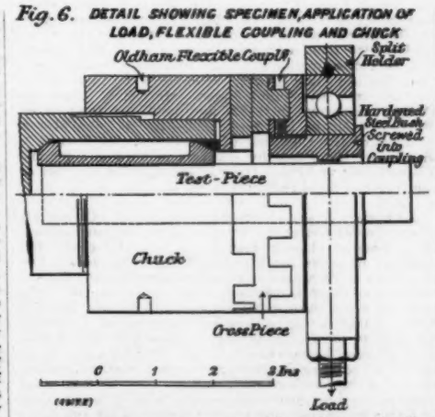
Fig. 5. ARRANGEMENT OF SLIDING ABRASION TESTING-MACHINE



be high, it will be seen from the values of the scleroscope hardness after rolling, given in Table I, that in the case of the manganese steels this was practically doubled by the rolling, whereas that of the hardened steels was only increased by amounts ranging from 4 to 15 per cent. It is of interest to note from the figures that, even when this increase of hardness is allowed for, the resistance to rolling abrasion of the manganese steels is still considerably higher than would have been predicted from the ball hardness tests.

As regards the nature of the test, it may be assumed that, on first putting on the load, the yield-point of the material of the specimen on an extremely narrow strip of the surface of contact is exceeded, and that slight deformation takes place depending on the radius of the wear ring and the amount of the load. After a few revolutions, therefore, there will be a thin ring of material round the specimen which has been permanently strained, and whose resistance to deformation is greater than that of the original material. Wear will then begin to take place by the gradual disintegration of this ring under the repeated loadings, and also under the extremely small but definite elastic slipping of the surfaces over each other, which is the well-known characteristic of rolling. Another characteristic of the test is that part of the material worn away during the progress of the test appeared to be rolled into the surface again, and finally came away in flakes. In the description of Mr. Saniter's machine* it is stated that the speed of the machine is such that the abraded particles are removed by an induced current of air. This effect may be an advantage or otherwise, according to the similarity obtained to the conditions of practice. If the comparison required is the relative wear of steel rails, it would appear that the re-rolling action is a more exact copy of practical conditions of use than when it is prevented. It will be clear, however, that in this test what is actually measured is the resistance to disintegration of already de-

Fig. 6. DETAIL SHOWING SPECIMEN, APPLICATION OF LOAD, FLEXIBLE COUPLING AND CHUCK



the relative resistance to wear under conditions of rolling abrasion under heavy loads, *i.e.*, such as the wear of steel rails, the test was a comparatively easy and rapid method of obtaining the information desired, if the following precautions were observed :—

(1) The fixing of the specimen so that its axis is accurately in line with the axis of rotation of the chuck.

(2) Frequent renewal of the wearing ring, and calibration of each new ring on a specimen of standard material.

The reason for these precautions is that any slight vibration of the specimen increases the rate of wear, and this vibration may be set up by want of alignment of the specimen or by unequal wear of the wearing ring.

From the foregoing discussion of the characteristics

the slip of the ring over the specimen would be π (D — d) inches per revolution. The chief practical difficulty of the device appeared to be the difficulty of lubricating the sliding surface of the Oldham coupling so that it would run satisfactorily at 2,200 revolutions per minute, and it was evident that if the amount of sliding was large, that is, D considerably greater than d, there was a strong probability that seizing would occur. The chances of successful working appeared sufficient, therefore, to justify a trial of the method, and a design was got out. The details of the machine are shown in Figs. 5 and 6. The cross-piece of the coupling was made of brass with four slots on each side, to make the wearing surface fairly large. On the completion of the machine some preliminary tests were made with different rates of slip, and it was found that with a load of 410 lb. the sliding surface of the coupling worked satisfactorily up to a slip of $\frac{1}{4}$ in. per revolution of the specimen, but that beyond this value there was a tendency to seize. The tests were accordingly carried out at this value of the slip. The results were quite satisfactory, but it was evident that if the tests were to be comparable with the wear of tools, gauges, pins, &c., it would be necessary to prevent the action referred to when discussing the previous tests, by which some of the abraded particles were continually re-rolled into the surface. This was accordingly done by directing a strong air-blast from a compressor on to the surface of the specimen during the whole of the test. By this means the abraded particles were removed, and any rise of temperature in the specimen was prevented.

The results of the tests by this method, which may be called a sliding abrasion test, were, in one important particular, in marked contrast to those obtained by the rolling abrasion method, in that they indicated a possibility of making a wear test without gradually impairing the condition of the worn surfaces. For example, taking an extreme case, even when the loads on the wearing rings were the same in the two methods, there was very little evidence in the sliding abrasion test of that gradual hardening of the surface as the test

* Journal, Iron and Steel Institute, 1908, No. 3, p. 75: ENGINEERING, vol. lxxxvi, page 493.

TABLE I.

Marks.		Hardening.	Tempering.	How Tempered.	Brinell Hardness No.		Scleroscope No.		Wear.	Resistance to Wear.
One end	Other end.	Temp.	Temp		Unworn surface.	Worn surface.	Unworn surface.	Worn surface.		
8986–1	1	850 deg. C. Oil	None	—	720	—	98	108	55	18
8986–1	2	Do.	200 deg. C. Air ..	Oil Bath ..	720	—	98	113	52	19
8986–1	3	Do	300 deg. C. Air ..	Do. ..	605	605	90	101	62	16
8986–1	4	Do.	400 deg. C. Air ..	Melt ..	565	565	86	90	69	14.5
8986–1	5	Do.	500 deg. C. Air ..	Gas Muffle	453	455	77	80	80	12.5
8986–1	6	Do.	600 deg. C. Air ..	Do. ..	420	420	67	71	71	14
1 M	Manganese steel		950 deg. C. water	—	219	230	34	71	33	30
2 M	Do.	do.	As forged	—	277	284	44	78	37	27

proceeded which was so characteristic of some materials under the rolling abrasion test. This was shown by making tests with the scleroscope on the surfaces before and after abrasion.

As might have been anticipated, an important condition affecting the rate of wear was the freedom of the surfaces from the slightest trace of lubricant. In the early stages of the work it was found that occasionally a little oil was carried over from the air-compressor by the compressed air, with the result that the test was a complete failure, and it was not until special precautions had been taken to keep the surfaces dry that consistent results were obtained. Under these conditions, however, repetitions of the tests on the same specimen were in very good agreement.

It was considered, therefore, that for the object of the present investigation, *i.e.*, the comparison of the results of the ordinary ball hardness tests with those of a wear test of a satisfactory character, the machine here described would be quite suitable, and a series of tests on a wide range of materials was carried out. A large number of these materials were kindly provided by Sir Robert Hadfield, who also undertook the hardening of the special wearing ring used for the tests. In addition, tests were also made on some samples of steel used for the manufacture of gauges and other materials available at the National Physical Laboratory for the purpose of the work.

The determinations made on these samples were as follows:—

(1) The Brinell hardness number for the unworn surface (calculated as described above).
(2) The Brinell hardness number for the worn surface.
(3) The scleroscope number for the unworn surface.
(4) The scleroscope number for the worn surface.
(5) The wear expressed as thickness of surface layer worn away in mils. per 1,000 ft. of slip.
(6) The relative resistance to sliding abrasion or the reciprocal of the quantities in column 5.
(7) Ratio of Brinell hardness number to scleroscope number.
(8) Ratio of Brinell hardness number to resistance to sliding abrasion.

The values are tabulated in the order stated in Table II.*

The load on the wear ring at which these tests were carried out was the same as in the previous tests with the rolling abrasion tests, namely, 410 lb.

The reason for using a high value of the load in the sliding abrasion tests was that, although a satisfactory rate of abrasion could be obtained with loads as low as 100 lb., the wear of the specimen was much more uniform when the higher pressure was used. At the low pressures there was a tendency for the specimen to become elliptical, so that the determination of the wear was difficult. The adoption of the high value, on the other hand, undoubtedly caused the relatively small hardening up of the surface of the specimen which was detected in a few instances under sliding abrasion.

(To be continued.)

Lignite in Germany.—Lignite deposits are at present a much-sought-after commodity in Germany, and several large deals have recently taken place. The buyers are generally large industrial concerns or electricity works. Thus the Rhenish-Westphalian Electricity Works, of which Herr Hugo Stinnes, just elected a member of the Hamburg-American Steamship Company, is the chairman, are stated to have bought the majority of the shares in the Neurath and Prinzessin Victoria lignite concerns, through the medium of the German National Bank, at a price of 3,500 marks per share. This is another instance of that overlapping and combining process which at present is so much in vogue in Germany. The large Baden Aniline and Soda Company has also recently secured important lignite deposits, those known as the Elise II concern, for a cash payment of between 9,000,000 and 10,000,000 marks. The Elise II deposits were bought by the selling concern, the Werschen-Weissenfelder Company, four years ago, for rather more than 4,000,000 marks, but the deposits had not then been opened out. The Elise II deposits are calculated to contain some 850,000,000 tons open to surface working. The Hochst Dye Works were also supposed to be desirous of securing the lignite deposits in question, but a fairly close connection exists between this company and the Baden Aniline Works. The German Petroleum Company has likewise acquired an interest in some lignite deposits, those of the Rositzer Lignite Company, the lignite in question being particularly bituminous.

* This table, with the comments on the results it records, is held over until the next issue of Engineering.

NOTES FROM THE UNITED STATES.

Philadelphia, November 22.

Negotiations are pending to-day for enormous quantities of export steel. Norway is an urgent buyer for 30,000 tons. A further advance in pig-iron is in sight, after four advances within a month. Steel rails have been advanced 5 dols. within a week; the rail mills are practically sold up for 1917 and an abundance of inquiries are still in sight. Basic iron has reached 27 dols. a ton, and all other kinds have advanced in like proportion. Heavy sales of pig-iron are recorded to the larger steel producers who, ordinarily, have pig-iron to sell. The present outlook is for a greater pressure, as orders are in sight at every point of view. Locomotives and car orders are crowding along, and the number of locomotives and cars wanted is not known on the market but is beyond estimate. The New York Central has increased its order by 7,000 cars, and many other roads are expecting finally to close next week or the week after. The advances in prices do not seem to check demand, but rather increase it. Domestic requirements are opening up where it was supposed they had been covered, but the presumption is that the more recent orders are for a distant delivery. There is nothing in sight to indicate any decline in the urgency of demand. Steel stocks are advancing in the stock market, and quotations are based upon present earning capacity, which buyers hope will indefinitely continue. The price of coke is rising. The only question asked is not "How much?" but "How quick?"

Royal Society of Arts.—The juvenile lectures will be delivered by Mr. Alan A. Campbell Swinton, F.R.S., on "Electricity and its Applications." The lectures, which will be fully illustrated with experiments, will be given on Wednesdays, January 3 and 10, at 3 p.m.

Personal.—Messrs. James Gordon and Co., water power engineers, having had their offices in Canada House, Kingsway, requisitioned by the War Office, have removed to temporary offices at Queen's House, Kingsway; the telephone number and telegraphic address remain the same.—Messrs. Henry Faija and Co. (D. B. Butler, Assoc. M.Inst.C.E., F.C.S.), of the Portland Cement Testing Works and Chemical Laboratories, 41, Old Queen-street, Westminster, have left that address and are at 6, Earl-street, Westminster, S.W.

The Late Mr. Robert Colver.—We regret to have to record the death, which occurred on the 2nd inst., at his residence, Rock Mount, Ranmoor, Sheffield, of Mr. Robert Colver, J.P., partner in the well-known firm of Sir Joseph Jonas, Colver and Co., Limited. Mr. Colver was born in Sheffield in 1842; he was educated in Sheffield, and was apprenticed as a farmer to one of his uncles. He then served his articles as a land valuer, but abandoned work on the land for commercial pursuits in 1873, becoming shortly afterwards partner to Sir (at that time Mr.) Joseph Jonas. Mr. Colver joined the Cutlers' Company in 1882, and held the position of Master Cutler in the year 1890–91. He was also a member of the Chamber of Commerce, and became a Justice of the Peace for the city in 1910 and for the West Riding in 1911. He was appointed a member of the Iron and Steel Institute in 1877.

American State Nitrogen Projects.—On behalf of the United States Government a Norwegian engineer is at present visiting Europe in order to study the different methods for manufacturing nitric acid. The American Government has comprehensive plans for the erection of State factories for the production of nitric acid, for which purpose 20,000,000 dols. are said to have been allotted. The method or combination of systems which suits the United States best has now to be found. The problem has been solved in different manners in different countries. The Norwegian method, which works at the smallest cost, requires four to five times more power than the other processes, and for the quantity of nitric acid which America will require in case of war—about 200,000 tons annually—the Norwegian process will absorb some 500,000 h.p., which is a heavy item for a country like America, with its expensive power. The consumption in times of peace only amounts to 30,000 to 40,000 tons. The method to be adopted will consequently have to be adaptable to the manufacture of artificial manure in times of peace and to the manufacture of nitric acid in war time. America uses almost exclusively mixed manures, containing potash, nitrogen and phosphorus; nitrate of ammonia, which also can be produced by the Norwegian process, can be used in this blending, but is inferior to sulphate of ammonia. The United States own some waterfalls in Tennessee, where the first factories in all probability will be located.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

South Yorkshire Coal Trade.—There has been no material change in the general position during the past week, but at the same time there has been greater pressure put upon collieries for certain classes of coal. The position of steam fuels is very strong, the local demand during the past week being one of the heaviest on record. Thanks to the services of the Government-appointed committee for directing supplies, works are able to rely upon a certain quantity at fixed and regular intervals, and the recent tightening of the market has only affected them in so far as to limit the purchases for stocking purposes. The smaller kinds of manufacturing coal are also well held. Cobbles are a big demand, and steam nuts, though still a short supply, are an improvement on the week. There is considerable activity in slacks. Blast-furnace and gas cokes are in full request at high prices. House coal shares in the general briskness, and there has been heavy town and country buying. Shortage of tonnage has had a marked effect upon the export trade, whilst licences are being issued more sparingly. Quotations:—Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstones, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; smalls, 7*s.* 6*d.* to 8*s.* 6*d.* per ton.

Iron and Steel.—The material market continues to excite chief attention, and there has been considerable buying of all brands. Large contracts have been recently placed for prompt deliveries of forge qualities, both Derbyshire and Lincolnshire, but the foundry makes do not attract much inquiry. Basic iron is now arriving in abundant parcels, and local requirements are fairly well met. Hematites are also in a satisfactory position from the point of view of the consumer, supplies being to hand in ample and regular fashion, and quotations keeping well within the official maximum. The output of steel billets is fully absorbed by contractors, and those who are not wholly supplied in this way are in a very unenviable position, for open market sales reveal that the commodity is scarce and dear. Soft basic billets are fully 14*l.*, and both Bessemer and Siemens acid billets range from 14*l.* to 15*l.* American billets, with delivery at Liverpool, average about 14*l.*, but they are not nearly so profitable to works as the purer English products. The Swedish position has not undergone any vital change during the week, and the imports are still on the small side. Swedish pig has advanced in value to 27*l.* and 28*l.* per ton, and bar iron is 42*l.* The outcome of this is to cause makers of many goods for which Swedish material has been considered indispensable to use English makes. The results are considered eminently satisfactory. There is something of a boom at the present time in tramway and railway works, whilst the demand for shipbuilding steel has increased beyond expectations. File and saw makers continue to enjoy unexampled prosperity. The lighter trades are busy, the orders for all classes of cutting tools being out of all proportion to the capacity for output. In this connection it is interesting to note exclusively that the well-known firm of Messrs. Arthur Balfour and Co. have undertaken a huge scheme whereby their output of high-speed and all manner of tools will be considerably augmented. New shops will be opened and installed with the most up-to-date plant. A new trade established during the war is the making of small magnets for magnetos, electric meters, ship's compasses, &c., and the larger ones for lifting purposes in the large works. Agricultural implement and machinery makers, who are losing skilled grinders through the operation of the Military Service Acts, are full up with orders until March or April next, and are in danger of being in arrears on their contracts. There has been a profitable business in sheep shears, orders having come from Australasia, the United States, Canada, South America, and South Africa. The general volume of foreign and Colonial trade is expanding, and typical recent orders are for tools, augers, files, saws, knives, hammers, machetes, hardware and cutlery.

Further German Industrial Combines.—The large Phœnix Mining and Iron Works Company has announced that the company has acquired the bulk of the shares in the Böcker and Haver Company, in Hohenlimburg, which manufactures principally cold-rolled strip iron, all the shares of the Fachingen Iron Ore Mining Company, and the majority of those of the Freier Grunder Iron Ore Company. This process of extension and amalgamation goes on unabated in several branches, or one might almost say in all branches, within the German industry, the result being the formation of some exceptionally powerful concerns.

Harbour and Canal Extension in Sweden.—The construction of the new Trollhätta canal has led to a series of other work in connection with harbours and waterways. It is now being urged that the canal between Lake Vänern and Lake Vättern should be improved so as to have the same depth and breadth as the new Vänern-Gothenburg waterway. At Kristinehamn extensive harbour works have been going on for several years, entailing an expenditure of some 4,000,000 kroner. The work is now completed and the new harbour is about to be opened. The depth is 4 m. (13 ft.) and quays, store accommodation and ample railway connections have been provided.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—More and more as the days go on is the workers' rôle in the great war being recognised, and in consequence the importance of all possible effort to maintain, and increase, the production of the supplies of manufactured steel necessary for the purposes of the Allies cannot be lost sight of. As it is, manufacturers are doing their utmost with the means at their disposal, yet with every ton of the output going either directly or indirectly to meet the demand, the cry is still for an increased tonnage. As soon as the new plant being laid down is completed, a very considerable improvement will take place. No effort is being spared in the endeavour to cope with the accumulated arrears rendered a foregone conclusion by the heavy press of orders. Mercantile work shows little or no improvement, the licence question remaining a difficulty. A stiffening in price is evident, but unavoidable. Steel ship plates are quoted 14*l.* 15*s.*, or thereabouts, per ton; boiler plates are 15*l.* 12*s.* 6*d.* and upwards; and angles fully 14*l.* 15*s.*

Malleable Iron Trade.—The greatest activity prevails in the malleable iron trade, the makers' only source of discontent being their inability to deliver their vast numbers of important orders with the necessary expedition. Every effort is being concentrated on the Government orders, which, naturally, form the bulk of the work at present on hand. The enormous demand has necessitated many of the mills being turned on to steel, with the result that less malleable iron is being turned out meantime. For "Crown" bars the current rate is about 14*l.* 12*s.* 6*d.* per ton, while 16*l.* 10*s.* per ton is being readily obtained for steel.

Scotch Pig-Iron Trade.—The demand for all classes of pig-iron is as pressing as ever, hematite, earmarked for war purposes, being consumed in astonishing quantity by the steel works. A fair supply of No. 3 foundry grade is available, though strictly, of course, under Government control. Prices keep firm, particularly for export, the rate being gradually increased. So far as the home values are concerned the maximum rates are demanded and willingly conceded.

Shipbuilding in November.—The returns for mercantile shipbuilding on the Clyde for November compare quite favourably with those of the other 10 months of the year, but they are far behind those of normal times. Four vessels have been launched, with a total of 18,050 tons, bringing up the gross total for the 11 months to 45 vessels, with a tonnage of 138,518 tons. During the corresponding period last year 75 vessels of 211,877 tons were launched, and even this was much below the average of former years. Up till now little apparent result falls to be noted in connection with the Government scheem to speed up mercantile shipbuilding, but under existing circumstances it has not been found either possible or expedient to rush matters—the movement has been made, and improved output will follow in the natural course of events. Meantime, although little new business has been intimated, work is plentiful and all the yards busy. In addition to the 4 vessels launched on the Clyde during November, another 7 vessels, totalling slightly over 3,000 tons, stand to the credit of other Scottish shipyard districts.

Union of Clyde Shipyards.—Intimation has been made public that the proprietors of two of the oldest established shipbuilding yards on the Clyde have agreed to join forces, the amalgamation being expected to be of much mutual benefit. The two establishments concerned are the Meadowside Shipyard, owned by Messrs. David and William Henderson, Limited, and the Pointhouse Shipyard, situated on the opposite bank of the Kelvin, and owned by Messrs. A. and J. Inglis, Limited, from both of which many notable vessels have been launched during the past 60 years or so. In the meantime, at any rate, the management of the two concerns will continue on the same lines as have now existed for a number of years—Mr. Fred. N. Henderson as chairman and managing director of Meadowside, and Dr. John Inglis, chairman of Pointhouse, with his sons, who are associated with him, as directors. In each case the record of work has been historically interesting, so that the new combination may be looked upon to carry on the best traditions of the past.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is rather more business passing in Cleveland pig-iron. Sales to local customers and buyers in Scotland are reported for this year's delivery, and there is pressure to buy for abroad. Home consumers, however, are well placed for supplies over December, and licences for export are not easily obtained except for old contracts. A moderate business over the first quarter of next year is reported, and buyers would readily purchase further ahead, but producers are disinclined to commit themselves to any extent for delivery beyond the first three months of 1917. It is gratifying to learn that forge iron is being taken up much more freely for mixing with the better qualities. Some makers are prepared to shade the maximum price to reduce their rather considerable stock of forge iron. For home consumption No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge, all stand at 87*s.* 6*d.*, and No. 1 is 91*s.* 6*d.*; for shipment to our Allies No. 3 is 98*s.*; No. 1 is 102*s.* 6*d.*; No. 4 foundry, 96*s.* 6*d.*; and No. 4 forge, 95*s.* 6*d.*: and for export to neutral countries No. 3 is quoted 105*s.* and upward, and No. 1 is 110*s.* and upward.

Hematite Iron.—Conditions in the East Coast hematite branch of trade are more conducive to business than they have been. Most makers are now quite prepared to give favourable consideration to offers on forward account, and further negotiations for substantial contracts over periods next year are proceeding. Home consumers are receiving adequate supplies on running contracts, and a fair amount of iron is available for export. Prices are steady. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, 137*s.* 6*d.* for shipment to France, and 142*s.* 6*d.* for export to Italy.

Output of Pig-Iron.—A commencement has been made in the rather long-expected increase in production of pig-iron by the restarting of idle plant. An additional furnace to make Cleveland pig-iron has been started at the works of Messrs. Bolckow, Vaughan and Co., and Messrs. Pease and Partners have put an extra furnace in to produce hematite iron. This increases the number of furnaces blowing on the North-East Coast to 75, of which 29 are making Cleveland pig, 32 are turning out hematite, and 14 are manufacturing special kinds of iron.

Stocks of Pig-Iron.—Stocks of pig-iron are very small. The quantity of Cleveland pig in the public warrant stores is now only 4,073 tons, 4,037 tons being No. 3 quality, and 36 tons other kinds of iron deliverable as standard. There are warrants in circulation for only 2,500 tons, all No. 3 quality.

Coke.—Demand for coke for local use keeps good, and values of the qualities needed are fully upheld. Average blast-furnace kinds continue to realise 28*s.* at the ovens, and up to 30*s.* 6*d.* at the ovens is still asked for qualities low in phosphorus.

Foreign Ore.—With a good deal of tonnage coming to hand imports of foreign ore to the Tees are likely to be rather heavy during the last month of the year. To date unloadings for December at the port of Middlesbrough are officially given at 18,610 tons.

Manufactured Iron and Steel.—As regards the finished iron and steel industries, there is very little new to report. Manufacturers are very busy. A considerable and increasing quantity of mercantile shipbuilding material is being turned out, but Government work still monopolises by far the most of producers' attention. To home customers common iron bars are 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* 10*s.* to 18*l.* 10*s.*; packing iron and steel (parallel), 12*l.*; packing iron and steel (tapered), 14*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 20*l.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; and heavy steel rails, 10*l.* 17*s.* 6*d.* For shipment common iron bars are quoted 15*l.*; steel ship plates, 13*l.* 10*s.* to 18*l.* according to diameter; steel sheets (singles), 20*l.*; and steel sheets (doubles), 22*l.*

Iron and Steel Shipments.—Though the November shipments of iron and steel from the port of Middlesbrough were not heavy, they were up to expectation. Those of pig-iron amounted to 31,656 tons, as compared with 53,610 tons for the previous month, and 48,036 tons for November last year. Despatches of manufactured iron last month were returned at 2,557 tons, and clearances of steel at 22,955 tons. Of the pig-iron shipped 30,571 tons went abroad and 1,085 tons coastwise, of the manufactured iron cleared 646 tons went abroad and 1,911 tons coastwise, and of the steel loaded 22,801 tons went abroad and 154 tons coastwise. Once more France was the largest receiver of both pig-iron and steel, taking 25,548 tons of the former and 20,324 tons of the latter, Italy being the second best customer for both pig-iron and steel, receiving 4,500 tons of the former and 520 tons of the latter. India, with an import of 270 tons, was the largest purchaser of manufactured iron.

Manufactured Iron-Workers' Wages.—The accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England have this week certified the average net selling price of iron rails, plates, bars and angles for the two months ending October 31 last at 12*l.* 17*s.* 1.91*d.* per ton as compared with 12*l.* 7*s.* 0.14*d.* per ton for the previous two months and in accordance with sliding-scale arrangements for the ensuing two months there is an advance of 6*d.* per ton on puddling, and 5 per cent. on all other forge and mill wages.

NOTES FROM THE SOUTH-WEST.

Cardiff.—The steam coal trade has been unsettled, dealing being checked by the uncertainties of the labour situation and the attitude of miners towards Government control of coal mines. There are some indications of an amicable adjustment of matters in an early future, pending which the Government agrees to pay the extra 15 per cent. in wages demanded by the men. With tonnage still scarce and stocks still excessive, prices have shown weakness in all sections, although for forward delivery colliery owners are not disposed to modify recent values for large or smalls. House coal, patent fuel and coke have shown scarcely any change. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 28*s.* to 30*s.*; Monmouthshire Black Veins, 29*s.* to 30*s.*; ordinary Western Valleys, 28*s.* to 29*s.*; Eastern Valleys, 26*s.* to 28*s.*; best bunker smalls, 18*s.* to 20*s.*; and cargo smalls, 12*s.* to 17*s.* per ton. In bituminous coal, good best households have made 25*s.* 6*d.* to 26*s.* per ton at the pits; No. 3 Rhondda large, 29*s.* to 30*s.*; smalls, 22*s.* to 24*s.*; No. 2 Rhondda large, 25*s.* to 27*s.*; and No. 2 smalls, 16*s.* to 19*s.* per ton. The latest quotation for patent fuel has been 36*s.* to 38*s.* per ton. Special foundry coke has made 62*s.* 6*d.* to 65*s.* for export; good foundry coke, 57*s.* 6*d.* to 60*s.*: and furnace coke, 47*s.* 6*d.* to 52*s.* 6*d.* per ton.

Western Trade Matters.—The Newport Gas Company finds it difficult to spare men for the war, and it is contended that if the strain of man-power continues the supply of the products which the Minister of Munitions desires to receive from gas undertakings will be jeopardised. The local tribunal has, however, decided that 100 of such men reconsidered must "join" by December 31.—Messrs. Evan Thomas, Radcliffe and Co., Cardiff, have acquired three steamers of 8,000 tons carrying capacity from builders at Sunderland and Stockton-on-Tees.—A meeting has been held at Cardiff of engineers representing various electricity supply undertakings of South Wales and Monmouthshire to discuss proposals for linking existing power-generating stations within the area. Mr. Chancey explained the object of the meeting, which was to further the supply of electricity in the national interest by linking up generating stations, both large and small. Mr. A. Ellis, city electrical engineer, Cardiff, was elected president, and Mr. L. W. Dixon, managing engineer, Merthyr Electric Traction and Lighting Company, Limited, vice-chairman. Further steps are to be taken as soon as additional information has been collected.—The accounts of the Stepney Spare Motor Wheel, Limited, Llanelly, show a net profit of 14,163*l.*, and a dividend is recommended at the rate of 10 per cent. per annum, 10,000*l.* being carried to the reserve fund.—The Hazelwood Shipping Company, Limited, gives its shareholders an interim dividend at the rate of 30 per cent. per annum for the past half-year. The company is managed by Humphries, Limited, Cardiff—Lord Rhondda, chairman.—Griffiths Lewis Steam Navigation Company, Limited, divides at the rate of 8 per cent. per annum for the past year; the value of the dividend is considerably increased by the fact that it is payable free of income-tax.—Negotiations for the sale of the Ariadne Steamship Company, Limited, of London, are now completed, the purchase having been made by Mr. P. Samuel, of P. Samuel and Co., managers of the Universal Steam Navigation Company, Limited, Cardiff and London. The Ariadne Company was formerly owned by Mr. Ruducanachi. Three vessels are owned by the Ariadne Company. The Universal Steam Navigation Company was formed some time since to amalgamate the Ardgle steamship companies, previously managed by Messrs. T. Samuel and Co., who started business as shipowners in 1904. They own the steamers Kathleen, Nora, Gwladys and Clifton Dale, totalling over 36,000 tons deadweight, and they have a steamer of 5,500 tons deadweight now building; by their purchase they will control nine steamers.—Half the Welsh tin-plate works are idle, the Morriston and Llanelly districts being greatly affected.—An application was made to the Patents Court on Friday by Mr. R. Tilden Smith, colliery proprietor, of Copthall-avenue, London, for a licence to use three patents belonging to the Metallgesellschaft of Frankfort for the roasting or smelting of ore. Mr. Smith said he hoped to apply the apparatus to iron ores, to which it had never been previously devoted in this country. The controller said a royalty basis might be renewed after the war, when the *status quo ante* was resumed. He thought Mr. Smith should have this licence now at a royalty of 50*l.* a machine. He would see that no unnecessary delay occurred in the issue of the licence.

BRITISH MANUFACTURERS REPRESENTED IN AMERICA.—H.M. Consul-General in New York (Mr. C. Clive Bayley) requests United Kingdom manufacturers who have branches, agents or other representatives in the United States to forward to him the addresses of such representatives, as these will be of great assistance to him in dealing with the frequent inquiries he receives from American merchants.

MANAGING DIRECTORSHIP OF MESSRS. J. SAMUEL WHITE AND CO., LIMITED, EAST COWES.—The Board of Admiralty have permitted Engineer-Captain J. W. Ham to retire from his position as Engineering Assistant to the Director of Dockyards, in order to enable him to accept the appointment to the joint managing directorship with Mr. John Smith, of Messrs. J. Samuel White and Co., Limited, who are very actively engaged in the construction of war material for the Admiralty. Captain Ham has been for 38 years associated with the Navy, beginning as a student in the Marlborough and studying thereafter as an assistant engineer at the Greenwich College. For 13 years he was continuously in service afloat in various types of warships. Except for one or two short commissions at sea he has subsequently been identified with the construction of machinery for the Navy, occupying ultimately the position of first assistant to the engineering manager at Portsmouth Dockyard, when amongst other ships built was H.M.S. Dreadnought. In 1907 he was appointed to the Dockyard Branch of the Admiralty, and soon afterwards succeeded Engineer-Rear Admiral Goodwin as engineering assistant to Sir James B. Marshall, Director of Dockyards. In this capacity he has been personally identified with the equipment of the various dockyards at home and abroad, including new establishments rendered necessary by the war. Indeed, during the past two years he has worked strenuously in connection with the maintenance of the efficiency of the fighting fleet, and has received on several occasions expression of the appreciation of the Lords of the Admiralty. His experience, therefore, should prove invaluable to the Isle of Wight firm, which has so long taken a prominent part in the building of ships of a special type for the Navy.

SALVAGE EQUIPMENT USED IN RAISING SUBMARINE F-4, U.S.N.

(*For Description, see Page 569.*)

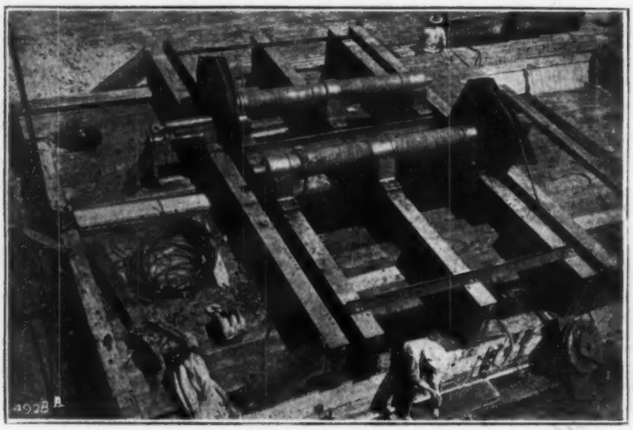


Fig. 1. Windlass Foundations and Windlasses in Place

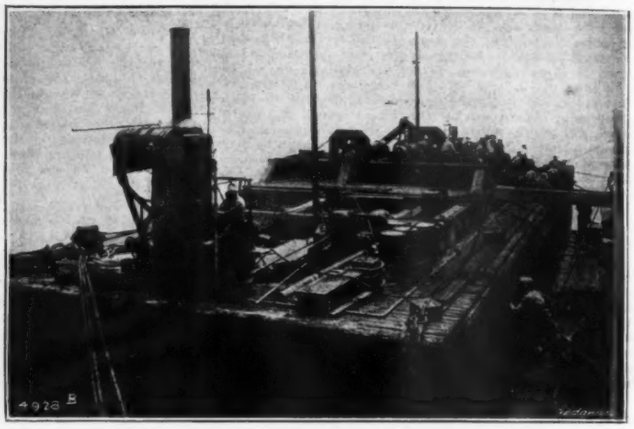


Fig. 2. End View of Scow, showing Running Gear.

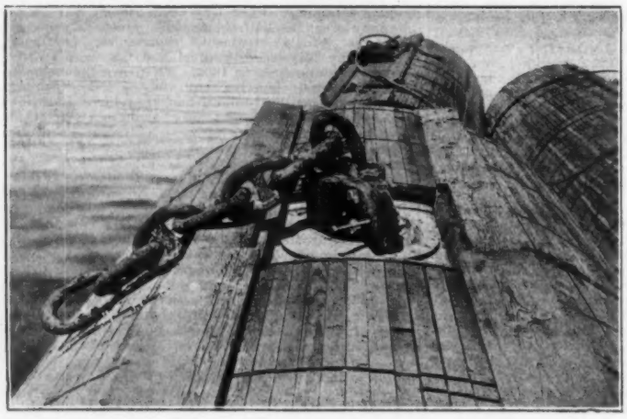


Fig. 3. Method of Securing Chain by Means of Clamp.

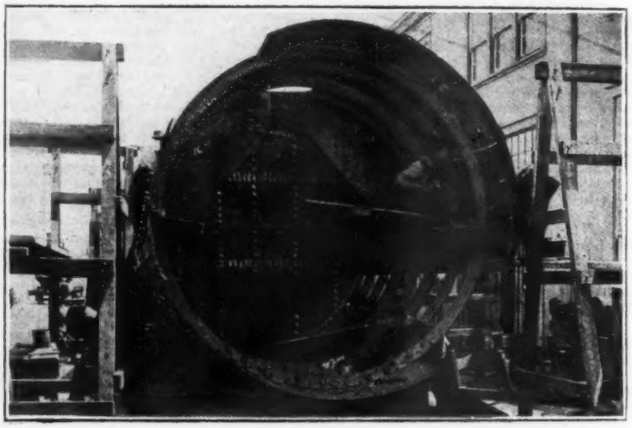


Fig. 4. Pontoons under Construction, Web Frame in Wake of Hawse Pipe.

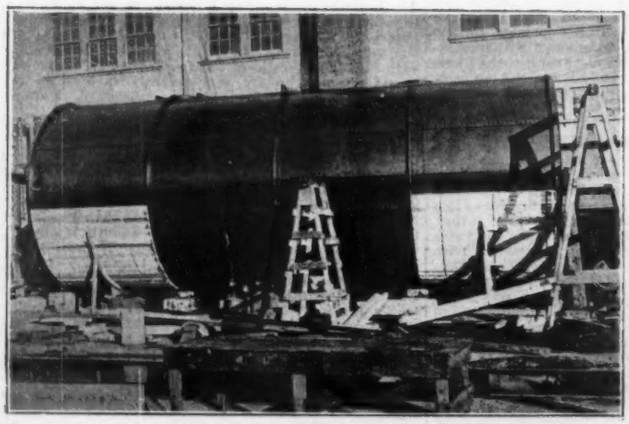


Fig. 5. Method of Applying Wood Sheathing to Pontoons.

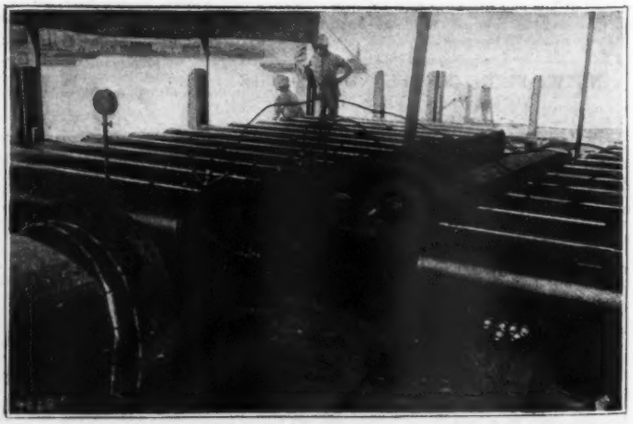


Fig. 6. Torpedo Flasks Installed on Coal Barge and 7-In. Pipe Manifold.

SALVAGE EQUIPMENT USED IN RAISING SUBM

(For Description, see

Fig. 14. SECTION ON HORIZONTAL CENTRE LINE.

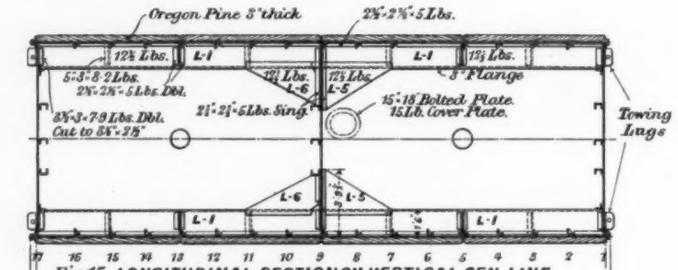


Fig. 15. LONGITUDINAL SECTION ON VERTICAL CEN. LINE.

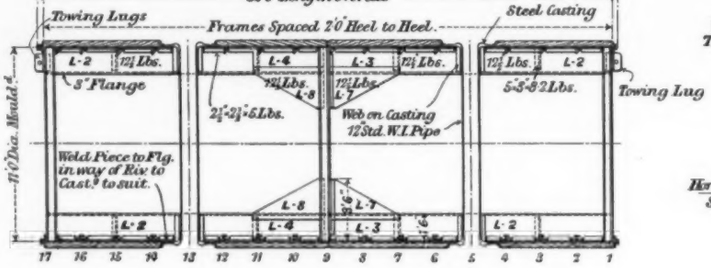


Fig. 16. EXPANSION OF OUTSIDE PLATING. ALL PLATING 15 LBS.

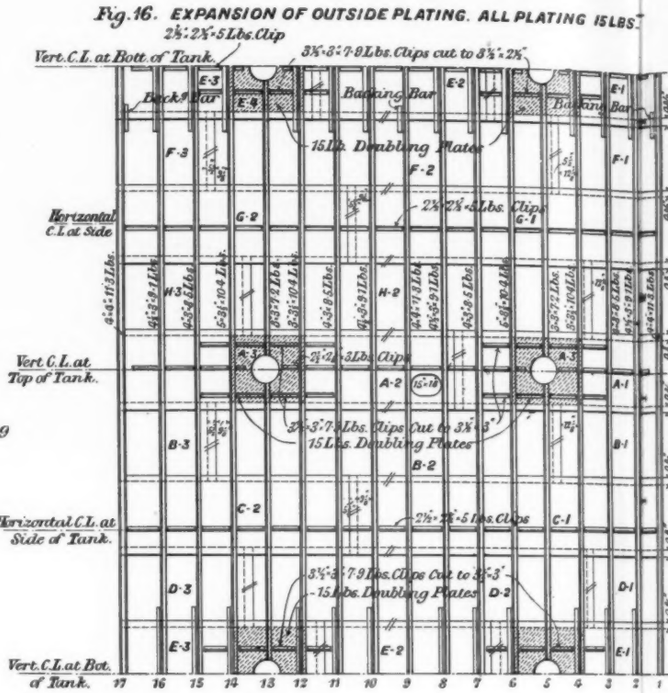

2½"·2½"·5 Lbs. Clip
Vert. C.L. at Bott. of Tank.
3½"·3"·7·9 Lbs. Clips cut to 3¼"·2½"
Backing Bar
Backing Bar
Backing Bar
15 Lb. Doubling Plate
2½"·2½"·5 Lbs. Clips
Horizontal C.L. at Side
2½"·2½"·5 Lbs. Clips
Vert. C.L. at Top of Tank.
3"·3"·7·9 Lbs. Clips Cut to 3⅜"·3"
15 Lbs. Doubling Plates
Horizontal C.L. at Side of Tank.
2½"·2½"·5 Lbs. Clips
3½"·3"·7·9 Lbs. Clips Cut to 3⅜"·3"
15 Lbs. Doubling Plates
Vert. C.L. at Bot. of Tank.
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Fig. 23. LONGITUDINAL GIRDER DETAILS.

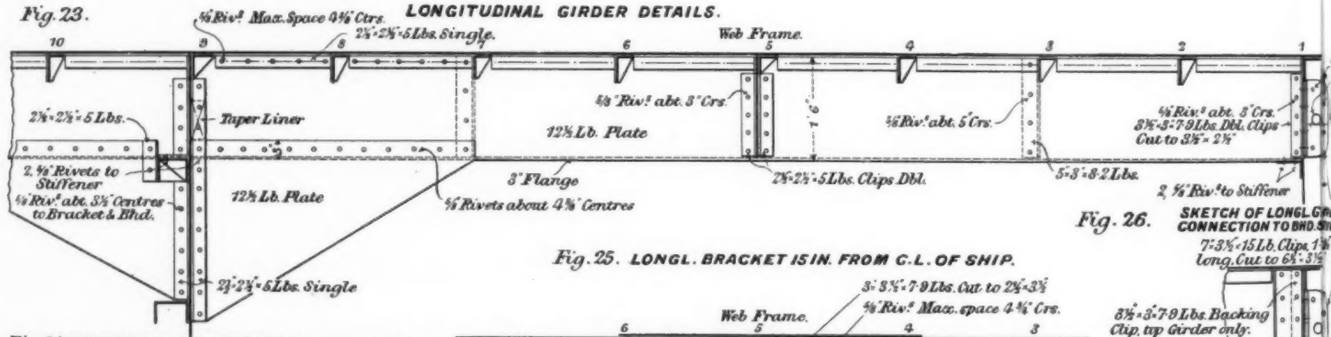

⅝" Riv.s Max. Space 4⅝" Ctrs.
2½"·2½"·5 Lbs. Single.
Web Frame.
10 9 8 7 6 5 4 3 2 1
2½"·2½"·5 Lbs.
Taper Liner
⅝" Riv.s abt. 3" Crs.
12½ Lb. Plate
⅝" Riv.s abt. 5" Crs.
⅝" Riv.s abt. 3" Crs.
8½"·3"·7·9 Lbs. Dbl. Clips Cut to 3¼"·2½"
2 ⅝" Rivets to Stiffener
⅝" Riv.s abt. 3½" Centres to Bracket & Bhd.
12½ Lb. Plate
3" Flange
⅝" Rivets about 4⅝" Centres
2½"·2½"·5 Lbs. Clips Dbl.
5"·3"·8·2 Lbs.
2 ⅝" Riv.s to Stiffener
2½"·2½"·5 Lbs. Single

Fig. 24. SKETCH OF LONGL. GIRDER CONNECTION TO BULKHEAD STIFFENER.

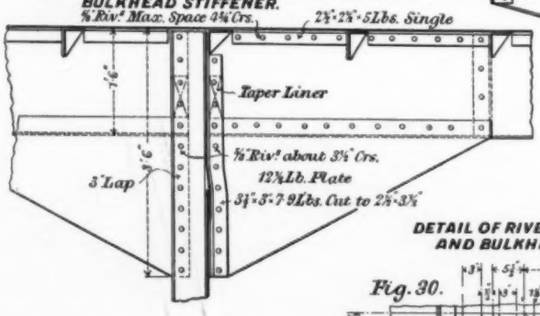


Fig. 25. LONGL. BRACKET 15 IN. FROM C.L. OF SHIP.

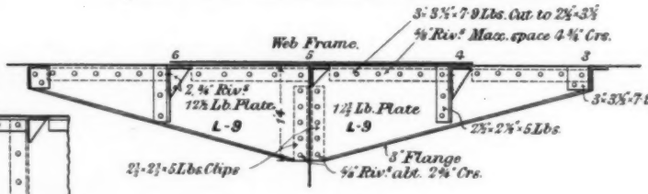
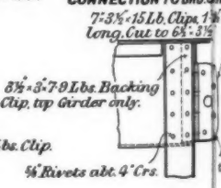


Fig. 26. SKETCH OF LONGL. GIRDER CONNECTION TO BHD. STIFFR.



DETAIL OF RIVETING FOR OUTSIDE AND BULKHEAD PLATING. ⅝" RIVS

Fig. 30.

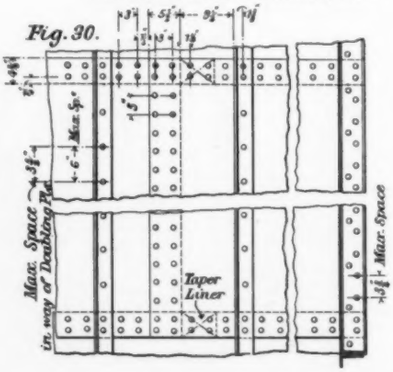


Fig. 29. PLAN VIEW OF CYLINDER IN WAY OF CHAIN PIPE SHOWING ARRANGEMENT OF SHEATHING BARS.

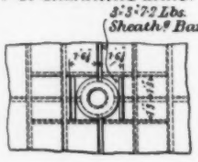
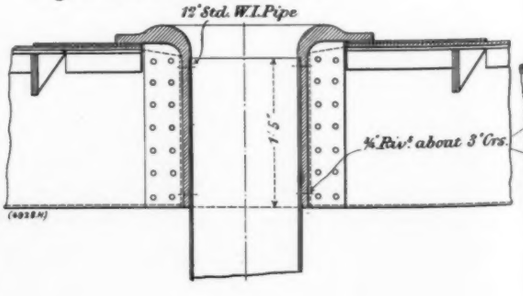


Fig. 31. LONGITUDINAL SECTION.



DETAIL OF CHAIN PIPE CASTING.
4 CASTINGS REQUIRED FOR 1 CYL. CAST IN

Fig. 32.

SUBMARINE F-4, U.S.N.; DETAILS OF PONTOONS.

escription, see Page 569.)

G 15 LBS.

Fig. 17. FRAME 3.
FRAMES 2,3,7,8,10,11,15,16 SIMILAR.

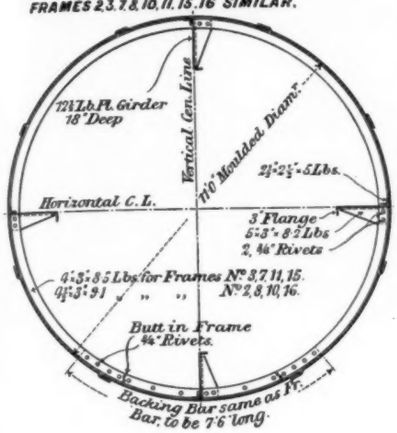


Fig. 18. FRAME 5.
FRAME No. 13 SIMILAR.

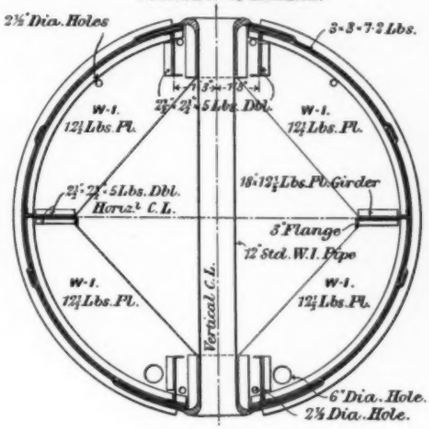
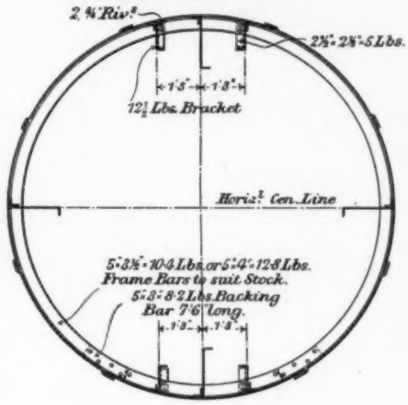
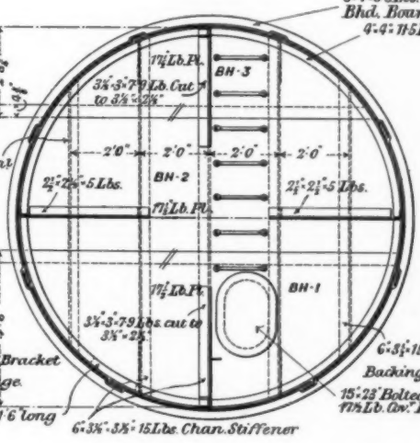


Fig. 19. FRAME 6.
FRAMES 4,6,12,14, SIMILAR.

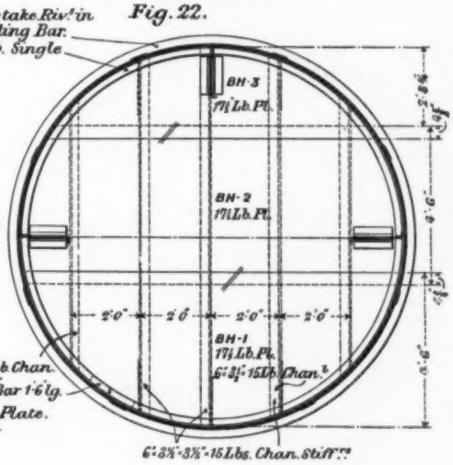


BRACKET FOR BULKHEAD STIFFrs
2'0" FROM C.L. OF TANK.
Fig. 20.

W.T. BULKHEAD No. 9.
Fig. 21.



W.T. BULKHEAD No. 1.
W.T. BULKHEAD No. 17 SIMILAR.
Fig. 22.



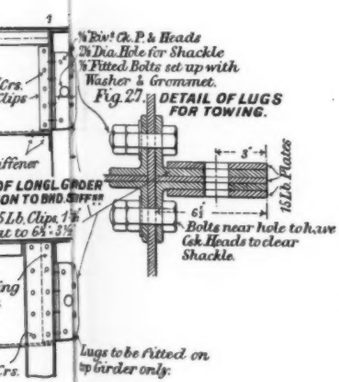


Fig. 27. DETAIL OF LUGS FOR TOWING.

Fig. 28.
LONGL. GIRDER RIVETING TO SHELL. ALL RIVETS ⅝" DIA.

IPE CASTING.
R I CYL. CAST STEEL.
Fig. 32. TRANSVERSE SECTION.

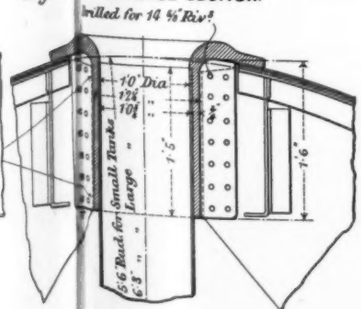


Fig. 33. PLAN VIEW.

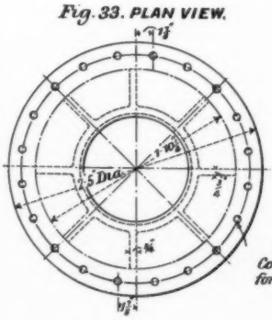
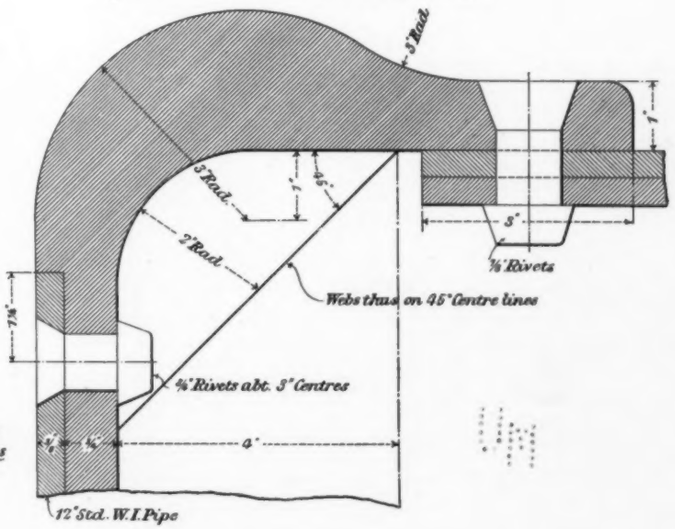


Fig. 34. DETAIL OF TOP PART OF CASTING.



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CONTENTS.

	PAGE
Literature	547
Books Received	548
The Institution of Mechanical Engineers	549
Vertical Milling Machine (*Illus.*)	551
The Caronte Viaduct (*Illus.*)	552
Industrial Notes	554
Fatal Explosion of a Digester	555
Report of the Hardness Tests Research Committee (*Illus.*)	556
Notes from the United States	558
Notes from South Yorkshire	558
Notes from the North	559
Notes from Cleveland and the Northern Counties	559
Notes from the South-West	559
Science and Industry	561
The Cost of Swedish State Electricity	562
The Smithfield Club Show	563
The Scientific Spirit	563
Notes	564
The German Cement Industry and the War	565
Government Appointments for Engineers	566
Tests on a Diesel Engine (*Illus.*)	566
Electron, Quanta and Relativity Theories	566
"Spark Ignition"	567
Progress with the Internal Combustion Engine	567
An Imperial Trust for Research	568
Diagrams of Three Months' Fluctuations in the Prices of Metals	568
Instrument for Indicating the Density of Smoke in Uptakes (*Illus.*)	569
Salvage Equipment Used in Raising Submarine F-4, U.S.N. (*Illus.*)	569
Battleship Design	572
Colonial Engineering Projects	573
ENGINEERING Patent Record (*Illus.*)	574

With a Two-Page Plate of the SALVAGE EQUIPMENT USED IN RAISING SUBMARINE F-4, U.S.N.; DETAILS OF PONTOONS.

NOTICES OF MEETINGS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, December 9, in the Wood Memorial Hall, Newcastle-upon-Tyne, at 2 p.m. The following papers will be open for discussion :—"The Estimation of Moisture in Coal," by Mr. T. F. Winmill, B.A., B.Sc. "The Absorption of Oxygen by Coal" (Parts VIII and IX), by Mr. T. F. Winmill, B.A., B.Sc. The following paper will be read or taken as read :—"Description of Best's Gauzeless Miners' Safety-Lamp," by Mr. W. Best.

THE ROYAL SOCIETY OF ARTS.—Monday, December 11, at 5 p.m. Howard Lecture.—"Coal and its Economic Utilisation," by Professor John S. S. Brame, Royal Naval College, Greenwich. (Lecture III.) Wednesday, December 13, at 4.30 p.m. Ordinary meeting.—"The Development of Imperial Resources," by Mr. Henry Wilson Fox, Director, British South Africa Company. The Right Hon. the Earl of Selborne, K.G., P.C., G.C.M.G., D.C.L., late High Commissioner for South Africa and Governor of the Transvaal and the Orange River Colony, will preside. Thursday, December 14, at 4.30 p.m. Indian Section.—"The World's Cotton Supply and India's Share in it," by Mr. John Alton Todd, B.L., Professor of Economics, University College, Nottingham. The Right Hon. Lord Emmott, P.C., G.C.M.G., will preside.

THE SOCIETY OF ENGINEERS.—Monday, December 11, at 3 p.m., in the apartments of the Geological Society, Burlington House, W., when two papers will be read :—(1) "The Sources of the Minerals Required by the Iron and Steel Industries of the United Kingdom," by Professor William G. Fearnsides, M.A., Sorby Professor of Geology, University of Sheffield. (2) "The Mineral Resources of the British Empire as Regards the Production of Non-Ferrous Industrial Metals," by Professor C. Gilbert Cullis, D.Sc., Assistant Professor of Geology, Royal College of Science, London.

THE JUNIOR INSTITUTION OF ENGINEERS.—Monday, December 11, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when Mr. Frederick William Lanchester, M.Inst.C.E., will deliver his Presidential Address, "Industrial Engineering—Present Position and Post-War Outlook." The retiring President, the Most Honourable the Marquis of Graham, D.L., C.V.O., C.B., will take the chair at 8 p.m.

THE SURVEYORS' INSTITUTION.—Monday, December 11, in the Lecture Hall of the Institution, when a paper will be read by Professor K. J. J. Mackenzie, on "Suggestions for the Improvement of Cattle Breeding in Great Britain." The chair will be taken at 5 o'clock.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SCOTTISH LOCAL SECTION.—Tuesday, December 12, at 7.30 p.m., at the Rooms, 207, Bath Street, Glasgow. Paper: "The Parallel Operation of Electric Power Stations," by Mr. J. S. Peck, Member.

THE COLD STORAGE AND ICE ASSOCIATION.—Tuesday, December 12, at 5 p.m., at the Royal Society of Arts, John Street, Adelphi, London, W.C., when a paper will be read on "Education and Research in the Refrigerating Industry," by Mr. J. Wemyss Anderson, Member, Dean of the Faculty of Engineering, Liverpool University.

THE ASSOCIATION OF ENGINEERS-IN-CHARGE.—Wednesday, December 13, at 8 p.m., at St. Bride's Institute, Bride Lane, Fleet Street, E.C. A paper will be read by Mr. S. G. Martlew, Member, on "Solid Fuels." Mr. W. H. Booth, F.G.S., M.Am.Soc.C.E., in the chair.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, December 13, at 8 p.m., in the Hall of the Royal Society of Arts, John Street, Adelphi, W.C., when Mr. F. W. Lanchester, M.Inst.C.E., will read a paper entitled "Worm Gears and Worm Gear Mounting."

THE OPTICAL SOCIETY.—Thursday, December 14, at 8 p.m., at the Rooms of the Chemical Society, Burlington House, Piccadilly, W. The following will be read and discussed :—"The Refractometry and Identification of Glass Specimens—especially Lenses," by Mr. L. C. Martin, D.I.C., A.R.C.Sc., B.Sc., Imperial College of Science and Technology. "A Workshop Method of Determining the Refractive Index of a Piece of Glass having One Flat Surface," by Dr. R. S. Clay.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, December 14, at 8 p.m. "Colonial Telegraphs and Telephones," by Mr. R. W. Weightman, Member.

THE ILLUMINATING ENGINEERING SOCIETY.—Friday, December 15, at 5 p.m., at the Royal Society of Arts, John Street, Adelphi, London, when an account of events during the vacation, including some suggestions regarding war economies in lighting, will be delivered by Mr. L. Gaster, Hon. Secretary.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, December 15, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne. The discussion will be resumed on "Works Organisation," by Mr. A. D. C. Parsons, B.A., Member, Mr. Edwin L. Orde, Vice-President, and Mr. G. H. Tweddell, Member.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, December 15, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster. Paper: "Variable Speed Gears for Motor Road Vehicles," by Mr. Robert B. Phillips, Member.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, DECEMBER 8, 1916.

SCIENCE AND INDUSTRY.

THE Royal Society, founded for promoting the development of "Physico-Mathematicall Experimental Learning," received its first charter in 1662 from the king, who in this instance, at any rate, belied the second moiety of the character given him by Rochester as one "who never said a foolish thing and never did a wise one." A new chartered society is, as Lord Crewe announced last Friday, now to be founded; also intended to develop experimental philosophy, but aiming less at satisfying the innate curiosity of humanity as to the constitution of the cosmos than in rendering more accessible the vast stores of potential wealth still locked up in Nature's treasuries. Some may consider the aim of the new corporation as all but admittedly ignoble, but the philosopher, poet and philanthropist are only able to pursue their several vocations because the vast majority of mankind work in the main to definitely utilitarian ends. In introducing to Lord Crewe the deputation of the Board of Scientific Societies, Sir J. J. Thomson observed that whilst research in applied science might lead to reforms, that in pure science led to revolutions, and the general truth of this proposition will hardly be disputed. After the pioneer, however, comes the settler, and the object of the "Imperial Trust for the Encouragement of Scientific and Industrial Research" will be to assist on his way the courageous adventurer into the new territories discovered by the advance of what Mr. Swinburne has called raw science. The new body will differ, moreover, from the old Royal Society in receiving really substantial financial assistance from the national treasury, which has never proved other than niggard and parsimonious in the help hitherto afforded to scientific research. Following the precedent set by the one-time much-abused Navy Act, the grant made will not be dependent upon a yearly appeal to the House of Commons, but a large sum estimated to meet the needs of the next five years is to be secured to the new corporation, which it is hoped will also receive substantial aid from manufacturing firms. With an intelligence as welcome as it is unprecedented the Treasury has agreed that sums thus bestowed may be treated as working expenses of the contributories, and deducted before the assessment of profits for income-tax or surplus profits tax. Perhaps after this first essay in the common-sense treatment of industrial profits the same authorities may ultimately see their way to an adequate allowance for the obsolescence and depreciation of plant.

One objection will surely be raised by a certain class of politician to the application of public funds to researches which may ultimately lead to the founding and building up of new industries. It will be said that public funds are being applied to the foundation of private fortunes, the usual assumption being that the sole beneficiare of such remarkable industrial developments as were being brought to fruition by Samuel Cunliffe-Lister is the promoter himself. Such a proposition is only logically tenable by one who holds that all life is a mistake, and that consequently the provision of means of livelihood to vast populations is merely an added outrage on humanity at large. Again, such objectors certainly fail to realise the great gulf which in most cases exists between discoveries, even in applied science, and their commercial application. This point is very well brought out in a paper describing the aims of the National Physical Laboratory, recently read by Dr. Rosenhain before the West of Scotland Iron and Steel Institute. Dr. Rosenhain observes that even in laboratories devoted to applied science the experimenter always, and quite properly, endeavours to reduce to its simplest terms each problem that presents itself. If he be studying alloys, he uses materials as pure as he can get them, and he carefully regulates furnace temperatures and rates of cooling. As a consequence, when an attempt is made to obtain the same results with commercial metals and on a commercial scale, alloys which may have been found tough and strong in the laboratory may prove brittle, weak and worthless in the factory. A new series of researches has accordingly to be carried out in the works in order to discover some way of attaining under actual practical conditions the valuable qualities of the laboratory specimen. Experiments on an industrial scale are, however, extraordinarily expensive. Lister, for example, is reported to have spent 250,000*l.* and brought himself to the verge of bankruptcy before he succeeded in his schemes for utilising silk waste. The final result—that a yarn worth 23*s.* a lb. was produced from raw material costing 6*d.* to 1*s.* per lb.—naturally yielded a remarkable profit even on heavy initial outlay, but only a crank would deny it was well earned.

The final step in practicalising any strikingly

novel departure will probably always be due to individual initiative and enterprise. Co-operation works well up to a certain point, but results in reforms rather than revolutions. In the aggregate, the value of such reforms is extremely high, and in the past this country has suffered much from a most inadequate appreciation of the fact. The new corporation will go far to correct this by providing accurate data on which manufacturers can build, and by undertaking investigations in which the prospect of benefit to any individual firm is too small to make the financing of the research by private undertakers practicable, though it may be very substantial to the industry taken as a whole. Few shipbuilding firms, for example, are in a position to establish experimental tanks of their own, but the Yarrow tank at the National Physical Laboratory affords to all the means of obtaining accurate data on any special piece of work they may have in hand. In any case, a great multiplicity of tanks would be a useless tax on the industry at large, though it would be equally, if not more, disastrous in the end were overlapping entirely avoided and the work concentrated at one centre. Repeated experience has shown the prime necessity for the progress of independent thinking centres. French artillery, for example, never reached its exceptional degree of excellence so long as private firms were prevented from taking part in this particular form of industry. We note that one of the first problems which it is proposed to tackle is that of economising fuel, and this field of research should certainly well repay cultivation.

Under the new scheme a large part will naturally be played by the National Physical Laboratory, which, in spite of inadequate help grudgingly afforded in the past by the Treasury, has proved that in suitable conditions our contributions to applied science need not rank below the standard we have long maintained in the more academic branches. The Government grant to this laboratory was originally 4,000*l.* per annum, which has since been increased to 7,000*l.*, and an additional 14,400*l.* was provided in 1916–17 for aeronautical researches. Never did a nation spend a few thousands more profitably, as the researches at Teddington have backed most effectively the pluck and enterprise of our aviators. Even with this addition—earmarked for a special purpose—the total grant still makes a poor show in comparison with the 100,000*l.* per annum provided for the Bureau of Standards at Washington, or the nearly equal sum appropriated to the Reichsanstalt at Berlin. Fortunately the total receipts for the Teddington institution are substantially augmented by fees for work done, but even so, the gross sum is less than one-half the endowment of the Washington establishment.

Fortunately, moreover, the value of research work done is never directly proportionate to the expenditure incurred. At the Reichsanstalt, in particular, much of the work done is of secondary importance, whether considered on the basis of intrinsic value or of the reliability of the results published. It is, in fact, impossible to buy genius in the open market, and the more completely work is organised the less relatively is the opportunity afforded to the man of exceptional ability. The highest degree of precision in physical measurement, for example, will always be a matter dependent in the main on individual capacity rather than of lavishness of equipment. Particularly valuable work has been accomplished at Teddington in the fields of metallurgy and of aeronautics, in which departments it perhaps leads the world; but this is in the main due to the ability of those directly responsible for the investigations made.

It is, perhaps, not generally known that the laboratory is not a Government department or a branch of the civil service; this peculiarity doubtless originated in the reluctance of the Treasury officials to put merely scientific men on the civil service pension list, and other arrangements have had to be made. Government departments, it will be remembered, consider a salary of some 30*s.* a week as adequate for a trained chemist, and competent draughtsmen are treated little, if any, better. In this reluctance to admit that success in scientific work should be rewarded on a similar scale to that of lawyers, politicians and literary men, the departments have no doubt the hearty support of the latter. When one of the Nobel prizes was awarded to, perhaps, our most distinguished physicist the papers were full of suggestions for the appropriation of this money to other than personal uses, but there has ever been a marked absence of gratuitous advice of this character when one of the prizes has fallen to a British literary man.

The situation at Teddington, deplorable as are the motives in which it originated, is not, however, without its compensations. The administration rests with a committee, and the staff are employees of the Royal Society and not civil servants. As a consequence, promotions are less governed by considerations of seniority than would be possible were the establishment under direct Government control. The Treasury, however, does fix a limit to the maximum salaries paid, and as a consequence there is now a danger of some of the best of the staff seeking service elsewhere. Another great advantage of the Royal Society control is that such funds as have been available have been expended in equipment in place of on architecture. Public bodies, when they do contribute to scientific or technical institutions, are extremely prone to demand striking architectural effects rather than adequacy of either equipment or staff. The latter are generally inadequate in numbers, and even in the higher posts are paid far less than falls to the lot of the successful in other professions.

THE COST OF SWEDISH STATE ELECTRICITY.

We have at different times and at considerable length described the important hydro-electric power stations built and worked by the Swedish State at Trollhättan, Porjus and Alfkarleby, and we now proceed to give some particulars as to their working, the Royal Waterfalls Board, under which they act, having now completed their report up to the end of last year. This report also deals with some kindred matters, such as the regulation of rivers, canals and lakes, and the exploitation of waterfalls. These comprise Lake Vänern, the waterfalls purchased by the State for electrification of railways in the Motola river, the Iärlean, the Lagan and the Bolman. Further, a complete description of Sweden's waterfalls is in hand and, so far, deals with the Edefors fall in the Lule river area, the Lycksele and the Umgransele, of the Ume river area. The report on the extension of the Lödertelje canal is principally confined to waterways in Lake Mälaren, through Agne Sound, Kol Sound and Koick Sound. The exploitation of the Laholm falls has also been considered, but the plans are not completed.

The extension and regulation of the Trollhätta canal, so as to bring about an improved waterway between Vänersborg (Lake Vänern) and Gothenburg, had up till the end of 1915 entailed an expenditure of 1,400,000*l.* The work is divided into eight sections, of which sections 2 and 8 are completed, and on section 7 only some blasting remained to be done at the end of last year. The canal was sufficiently completed last month to permit of its being opened. To show its importance it may suffice to mention some of the quantities that had been handled up to the end of 1915:—

	Cub. m.
Blasting of rock above water ...	989,919
,, ,, under ,, ...	24,817
Earth removed in river or on shore	598,194
Dredging	2,125,000
Masonry for locks	83,977
,, bridges, docks, &c. ...	29,319

At the Trollhätta power station the work for the completion of the third stage has been pushed ahead, a considerable amount of blasting has been done, the concrete foundation for the machinery hall laid, and the horizontal tunnels for the tubes to turbines 9 and 10 have almost been finished, so have also the vertical tubes for turbines 9, 10 and 11. The excavation of the distribution basin has been taken in hand, and turbines for units 9 and 10 have been ordered.

Upon the apparatus for distribution 360,000*l.* had been expended by the end of 1915. The preparatory work for a 50,000-volt primary line from Trollhättan to Gothenburg has been proceeded with, but experts are still considering certain dimensions, &c. Also a number of secondary lines have been constructed during the year, and concessions granted for half-a-dozen 10,000-volt lines and one 50,000-volt line. The lengths of the Trollhättan high-voltage lines at the end of last year were:—

	Kilometres.
50,000-volt three-phase lines	220.5
10,000-volt three-phase lines	391.9
10,000-volt one-phase line	2.1
3,300-volt three-phase lines	5.5
	620.0

During last year the length increased about 70 km.

There has been no serious mishap to the plant during the year, nor has ice caused any disturbance or reduction in the supply of energy, thanks to the electric heating of the ice guards. The available capacity of the power station amounts to 56,000 kw., the maximum load during the year amounting to 49,100 kw. The increase of production of energy last year amounted to 27 per cent. The distribution lines have four times during the year been exposed to violent storms, once to a severe snowstorm (May 15) and once to severe hoar frost and storm.

The energy generated on the various systems amounted to:—

	Kw.h.
25-period system	279,088,800
50 ,, ,, ...	33,989
Continuous-current system ...	2,905,745
	282,028,534

The following quantity of energy has been transformed from the 25-period system to the 50-period system—8,340,355 kw.h., the average efficiency of transformation being 86.8 per cent.

The maximum output and the maximum load for the different systems have been as under:—

Maximum Load per 24 hours.

	Kw.h.
For the 25-period system (30/11) ...	987,400
,, 50 ,, ,, (20/1) ...	30,580
,, continuous-current system (22/12)	11,551

Maximum Load.

	Kw.
For 25-period system, with 50,000 volt (13/17)	18,800
For 25-period system, with 10,000 volt (27/11)	32,100
For 25-period generators, total (23/12)	49,100
For 50-period system (28/1) ...	2,160
For continuous-current system (4/12)	493

The accumulator battery during the year received 89,089 amp.h. and yielded 71,239 amp.h., its efficiency averaging 80 per cent.

At the end of 1915 the load on the power station was as follow:—

	Number.	Kw.
Transformers	342	66,222
Motors	2,742	37,704
Incandescent lamps ...	100,770	3,718
Arc lamps	32	25.5
Heating apparatus ...	1,151	2,058
Electric furnaces	39	32,960

The aggregate number of kw. is 76,466.

The cost of production per kilowatt hour at the Trollhättan power station was 0.046 öre (0.006 penny) per kilowatt hour, and revenue 0.915 öre (0.12 penny) per kilowatt hour. The aggregate outlay upon the power station, waterway, &c., at the end of 1915 amounted to 2,050,000*l.*, whilst the revenue for the year amounted to 134,000*l.*, and the expenses, including a contribution to the renewal fund (7.5 per cent. of the gross revenue for electric energy) amounted to 40,000*l.*, leaving a surplus of 94,000*l.*

In addition the Swedish State owns various properties, waterfalls, factories, &c., in the Gothenburg and adjoining districts, which had entailed an expenditure of 571,000*l.* at the end of last year, besides waterfalls (Skeen, Hjulsnäs, Tovhults and Traheryd and the Karsefors), bought with a view to the electrification of the State railways, which at the end of last year had entailed an outlay of 270,000*l.*

The amount of energy produced at Porjus during the year, that is, from February 12 for the one-phase system, and from January 29 to the end

of the year for the three-phase system, amounted to :—

	Kw.h.
To one-phase system	8,349,475
„ three-phase system	15,296,376
„ continuous-current system ...	800,360
	24,446,211

The maximum load was :—

	Kw.
One-phase system	10,250
Three-phase in the large-power section	5,800
Provisional station	320
Continuous-current system	220

The chief items of consumption were :—

	Kw.h.
One-phase energy :	
Kiruna-Rikegränzen Railway ...	8,349,475
Three-phase energy :	
Luossavaora–Kirunavoara Mining Company at Gellivare and Kiruna	14,685,100
For building work at Porjus, &c.	611,276
	15,296,376
Continuous current :	
For auxiliary purposes	336,100
„ power and light, power station	464,260
	800,360

The receipts for energy amounted during the year to 41,600*l.*, of which 28,400*l.* were derived from the State railways and 17,600*l.* from the Luossavaora–Kirunavoara Company. The working expenditure, including contributions to the renewal fund, amounted to 15,600*l.*, the surplus amounting to 30,400*l.* The working cost per kilowatt hour for 23,034,575 kw.h. paid for amounted to 0.043*d.*, which, it will be understood, is exclusive of interest and reduction of capital expended, and the revenue per kilowatt hour was 0.47*d.*

The third of the large Swedish State hydro-electric power stations, the Alfkarleby, was taken into use in the course of 1915, unit No. 1 on June 27, No. 2 on June 16, and No. 3 on September 26. The work on the steam reserve station at Västeras has been pushed ahead and plant ordered for the first section, including a de Laval steam turbine of 5,300 kw. normal and 7,300 kw. maximum capacity, and a Ljungström steam turbine generator of 5,000 kw. normal and 7,000 kw. maximum capacity. The distribution network of the Alfkarleby system has been proceeded with, and at the end of 1915 the length of the high-voltage line in working order amounted to :—

	Kilometres.
70,000 volts	205
40,000 „	84.5
20,000 „	78.3
	367.8

A number of concessions for the erection of additional lines have been granted during 1915.

The working of the power station has been perfectly satisfactory ; there have been no mishaps of importance, and there has been a sufficiency of water. The supply of energy commenced on June 16, 1915, at a pressure of 10,000 volts ; on July 1 the voltage was raised to 70,000 volts ; on July 8 the 20,000-volt distribution commenced, and on September 1 the 40,000-volt distribution, so that all the lines proceeding from the primary station were taken into use in the course of last year.

The amount of energy produced at the Alfkarleby power station during the year, at 50 periods and 10,000 volts, amounted to 23,417,000 kw.h., which was distributed as under :—

	Kw.h.
70,000-volt system	9,288,000
40,000 „ „	2,115,000
20,000 „ „	11,565,000
Own consumption, &c	449,000
	23,417,000

The maximum production per 24 hours was 291,550 kw.h. The maximum load on the generators was 14,100 kw. The revenue from electric energy supplied to subscribers amounted to 14,200*l.* for 18,588,540 kw.h., or 0.18*d.* per kilowatt hour. At the end of the year the Alfkarleby power station, with its distribution systems, &c., represented a sum of 950,000*l.*, the surplus on the past year's working being 8,600*l.*

The working of all the State concerns under the Royal Waterfalls Board seems to afford satisfactory results. These concerns are divided into three sections, those that yield a return, or, rather, an adequate return, those that yield no such return, and concerns not yet completely ready for working.

The first of these sections comprises the Trollhätta canal, the Trollhätta power station, the Porjus power station, and the Södertelje canal. They represent an aggregate capital of 2,620,000*l.*, and have yielded a surplus of 144,000*l.*, equal to 5.50 per cent., the percentage for Trollhätta and Porjus power stations being respectively 5.93 per cent. and 4.28 per cent. Exclusive of the value of the Crown water power of the two stations, the return would be respectively 8.66 per cent. and 4.45 per cent.

The second section comprises various waterfalls not yet exploited by the State, and other property, representing a capital of 1,040,000*l.*, which in the meantime has yielded 1.67 per cent.

The third section includes the unfinished portions of Trollhätta and Porjus power stations, the Trollhätta canal in process of extension, and the Alfkarleby power station, representing a surplus of 10,200*l.*, or 0.44 per cent. of the capital.

The three sections jointly, that is, all the State concerns and property under the Royal Waterfalls Board, represent :—

	£
An aggregate capital of	5,950,000
The gross receipts for 1915 amounted to	256,000
Working expenses	83,000
Surplus, which comes out at 2.87 per cent.	173,000

THE SMITHFIELD CLUB SHOW.

OWING to the restrictions imposed on exhibitors the display of machinery at the Smithfield Club Show is much less interesting than usual. An absolute veto was placed on the exhibition of engines of any kind, and as a consequence many firms, even amongst those most constant in their attendance in the past, did not care to take a stand. Some engine-makers have, however, entered an appearance, but at the most were unable to do more than show photographs or drawings of their standard products. Most are, of course, principally engaged on munitions of one form or another, and complaint is made that the authorities have not in all cases been well advised in the class of work demanded from certain firms. The works of some agricultural engineers, for example, are not well adapted for shell-making. The machine shop, compared with the foundry, smithy or wood-working shops, is relatively small. Hence, if such works are called upon to produce shells, the consequent congestion in the machine shop brings the greater part of the works almost to a standstill, and prices which may be adequate in shops specially laid out for shell production may thus involve somewhat serious losses in other cases.

Messrs. Aveling and Porter, Limited, of Rochester, occupy their usual stand and have a fine series of photographs representing their well-known road rollers and tractors. A somewhat similar display is made by Messrs. Wallis and Stevens, Limited, of Basingstoke, and Messrs. Foden, Limited, of Sandbach. Messrs. Saunderson and Mills, Limited, of Bedford, also enter an appearance. Messrs. Petter, Limited, of Yeovil, are another firm occupying a stand, but forbidden to exhibit. Moreover, much of the most interesting and important work they have in hand is for military or naval purposes, and cannot therefore be described. We note that the present capacity of these works is 4,000 engines per annum, ranging in size from 5 to several hundred horse-power. The military demand for heavy motor vehicles of all kinds is, of course, very great, and large batches are sent out weekly from every important builder in the kingdom. These vehicles, when sold off after the war, may do much to cheapen internal transport in this country, but the prospect will hardly be welcomed by road surveyors. An ingenious variant of the chain pump is exhibited at the stand of Messrs. Fastnut, Limited, of 115, Newgate-street, E.C. The chain in this instance consists of a number of dished washers of galvanised iron strung on a stranded wire, the ends being united to form an endless band. This runs over grooved wooden pulleys at top and bottom. The bottom pulley, which is suitably weighted, is lowered into the liquid to be raised, whilst the other is mounted on a shaft provided with the usual handle. On turning the latter a copious supply of water is raised to the surface. The water is stated to be held in between the discs by its surface tension and flung out by the centrifugal force, aided by the opening of the discs, as these pass over the top pulley. The chains are provided in standard lengths of 10 ft. and are easily coupled up to each other to make a chain suitable for any depth of well. The limit of depth is said to be over 500 ft., and as there are no valves or plungers, turbid or viscous liquids can be raised as well as water.

A simple form of hand-power hay-baling press is exhibited by Messrs. Degnall, Limited, of Willesden Green, N.W. A ratchet gear is used in giving the bales the final squeeze, but a quick-acting motion is provided for rapidly running the platen in and out,

The Worthington Pump Company, Limited, of India House, Kingsway, who had intended to show a considerable variety of internal combustion engines suitable for agricultural use, and in particular an oil tractor, are only able to exhibit illustrations of them. Other firms in a similar predicament are Messrs. Fairbanks, and Morse and Co., Limited, the Associated Manufacturers' Company and the Overtime Farm Tractor Company. Some useful tools for land clearing purposes are shown by Messrs. Trewhella Brothers, of 6, Alma-street, Birmingham. Amongst them is a form of log roller which, though in common use in the Colonies, is said to be almost unknown here. It consists of a 6-ft. wooden lever having at its outer end a spike sticking out at right angles to the axis of the lever, and a large hook hinged to the lever some 18 in. back. In use, the lever is rested on the top of the log and pushed up until the hook catches under the log. The latter is then easily rolled by raising the free end of the lever. A new post-hole auger is also shown at this stand. The special feature of this is the wide opening provided in front of each cutting edge. A flap valve is fitted to this opening, so that once the cutting edges have worked below any material none of this can get back when the auger is raised. The opening, on the other hand, is sufficiently large to pass stones of considerable size. A new wire strainer is also shown here, but can hardly be described in the absence of illustrations.

A varied collection of engineers' sundries is shown by Messrs. W. H. Willcox and Co., Limited, of Southwark-street, S.E.

THE SCIENTIFIC SPIRIT.

AT due and regular intervals we are reminded that the need of British industry is a greater amount of applied science and less empiricism. In part the implied accusation is just—scientific method and spirit do infuse a new impetus into pure commercial exploitation. Present endowment of research is pitiful in view of the profits of industry, which in turn expects such meagre provision to yield large commercial returns. Science and commerce are in essentials as far as the poles asunder, one considering no commercial basis and the other wholly absorbed in profit-making.

If it were more generally realised that scientific investigation is simply common-sense applied in sequence, and that it consists in the patient disentanglement of the whole series of factors in a given case, that it no more provides a direct solution of a problem than the mechanic's guess-and-try methods, save that it persists and takes few short cuts, the purely commercial man might be induced to show it more favour.

A collection of evidence becomes the basis of a theory, when all the work must be undertaken anew to prove such generalisation. It is at this point most often that lack of funds precludes experiments on a commercial scale to justify probabilities and make results secure. The investigator desires not merely to solve a single stage, but the entire series of stages, and find the limiting cases of the theory. Neglect of a single factor, the treatment of a mere symptom instead of the disease itself, means the forfeiture and complete failure to achieve the end in view,

Commercial testing and scientific investigation are not by any means the same thing. If the investigator be on testing of a commercial nature he is rightly considered a time-waster and a profound nuisance. Lack of this discrimination has caused some of the existing resentment against inspection methods. To expect any firm to turn their test bed into a laboratory experiment is unjustified by any point of view, and some firms rightly refuse to allow such liberties. The young engineer accustomed to testing plant under laboratory conditions has more than once attempted to carry on in the same way if entrusted with the technical testing of commercial plant, and cannot understand his reception by the makers. Ordinary shop testing is not scientific, and for many reasons—time being one—cannot be so regarded. In shop testing the essentials called for under specification, or the question of reasonable accuracy, are the ends required, not the solution of tests proving formulæ or total heat values. To obtain results sufficient, exercising discrimination and tact, obtaining a rational judgment of performance and workmanship under far from ideal conditions, represents the duty of the technician taking over stuff on behalf of a customer. If exhaustive and complete analysis of the performance of the job is required, this must be duly specified at the outset and its cost allowed by the manufacturer, who, in the majority of cases, is unable to afford the requisite facilities.

This aspect of inspection is apart altogether from the more exasperating one of sticking absolutely to the literal interpretation of the letter of a specification, though the man demanding scientific methods is often enough unqualified to come to a decision with regard to construction and workmanship.

Taking the question of scientific spirit in its more legitimate sphere, isolated facts and hasty judgment are useless, it is the co-ordination of evidence, connection link by link into a chain, which is pertinent to the issue. Every student who plots results honestly on squared paper is an exponent of the correct spirit. The virtues of graph construction from original experiment can hardly be overstated, the theory is a visible and tangible line capable of reasonable extension and legitimate interpolation.

If the critics are to be believed with regard to medicine, the engineer exercises much more scientific spirit in his daily work than the general medical practitioner. Certainly no experienced man ever treats a symptom, and every mechanic considers the qualifying factors before applying a remedy. There are no cure-all specifics in engineering practice, the alternatives are too numerous for any easy form of quackery. True, vivisection is easier for the engineer to practice in the case of mechanism, which approximates to surgery, but in the case of material he relies on a factor of safety to safeguard stability and strength. In any event, the mistakes of the engineer are not so readily disposed of by burial or cremation, and as a consequence the results of his handiwork are more visible.

The cultivation of the scientific spirit, popularly supposed to be in abeyance, is more generally practised than the lay critics realise. Evolution is a long and difficult process, and Nature took time and made mistakes, if the biologist be believed. Any man who cultivates a spirit of honest critical outlook, willing to experiment and loath to reach a conclusion without trying all possible roads, is travelling in the right direction.

Disbelief in the accepted methods or adopted conclusions is the beginning of further knowledge. Such an attitude pervades all engineering practice, hence the fact that more progress has been made in mechanical art than in any other single direction in the last decade. When a large and complicated problem calls for solution, it is delegated in sections to numerous investigators, each working in a definite small portion of the entire field. In this sense no industry is more highly organised than engineering, its field is now so vast that it embraces chemist, metallurgist, all the ramifications of the trade itself, the mathematician, the pure theorist, laboratory analysis and practical test. More delegation would be impossible; the chain from the ore to the finished product is long, in all directions improvements are in process of origination, each link dependent upon the link before. In one sense the entire chain is suspended from the steel-maker, and the last test is the eminently practical one of use and durability.

To argue that the scientific spirit is present in very minute quantity is to misstate facts. Everyone, from beginning to end, is an investigator in a portion of the entire territory. Certainly more opportunity for research apart from commercial cost is desirable, but the actual facts are unrealised by those who most loudly voice the belief that the scientific spirit is non-existent in practice, and a little more attention to the literal truth may help. Whatever may be the case in any other industry, so far as metals and their manifold uses are concerned the scientific spirit is present in quite large quantities even in Great Britain.

NOTES.

Deviation of Natural Gas from Boyle's Law.

In our issue of August 4 (page 116) we referred to the fact that natural gas is, in the United States, generally measured at high pressure (350 lb. per square inch frequently) and sold under the tacit assumption that the gas will obey Boyle's law, although it is understood that the natural gas is much more compressible than an ideal gas. The deviation from Boyle's law would be in favour of the company which buys at high pressure and distributes at low pressure. The question having been investigated by the Bureau of Mines, was recently brought before the American Society of Mechanical Engineers (September issue of the journal of this society) by Messrs. R. E. Earhart and S. S. Wyer, of Columbus University, Ohio, who confirmed the just-mentioned conclusions. It was shown during the discussion that there has been a good deal of experimenting on this problem by various methods. Earhart and Wyer compressed the gas in a glass capillary; they experimented with gas from eight sources, some "dry" gas, fairly pure methane, some "wet," containing up to 31 per cent. of what is conveniently styled ethane, but is really a mixture of various hydrocarbons, in addition to nitrogen and traces of carbon dioxide, &c. At pressures up to 48.5 atmospheres they observed deviations from Boyle's law of 12 and even of 20 and 32 per cent., but they did not think that there was any relation between the deviation and the percentage of ethane. On the other hand, G. A. Burrell and I. W. Robertson (Bureau of Mines) stated that they had found formulæ for deducing the compressibility from the composition of the gas. One feels a little doubtful, however, whether reliable analyses of sufficient bulks of gas have really been made in any of these researches. Several speakers referred to the undoubted influence of water vapour, but as nobody seems to have removed aqueous vapour or varied its amount, its influence cannot be allowed for. The results of other experimenters, obtained by diverse methods with diverse gases, naturally differed from one another. C. N. Cross, analysing Earhart's results, found them discordant, which is not astonishing, either, considering that there was evidence of a small amount of liquefaction in some of his experiments. The method used, according to E. O. Hickstein, at Wann, Oklahoma, is interesting. A known length (1 mile) of 12-in. pipe line is filled with the high-pressure gas and the gas then discharged at a constant rate through different types of meters. The time during which the gas escapes is taken by a stop watch (the period would be about 1,200 seconds), and from this reading and from the volume and the initial and final gas pressures (200 and 147 lb. per square inch in the first run, 47 and 6.75 lb. per square inch in the fourth, *e.g.*) in the reservoir (the pipe line) the rate of discharge is calculated, assuming Boyle's law to hold. The compressibility and deviation from the law can then be calculated from the excess of gas discharged. T. R. Weymouth mentioned another method, due to E. B. Rosa, of the Bureau of Standards. A small tank of known capacity is filled with the gas at high pressure; temperature and pressure having been determined, the gas is expanded at a very slow rate into a 10 cub. ft. meter-prover. The volume increase is deduced from the lift of the prover drum, and the true temperature of the expanded gas is finally determined by letting the gas flow through a hose with a thermometer in its path. The problem of the gas measurement evidently receives due attention, and the advantage is, as Mr. W. C. Baxter pointed out, not necessarily on the side of the buyer; for vapours of water and oil condensed after the gas has passed the meter would mean a shrinkage and loss to the purchaser.

Thermo-Electric Determination of the Critical Points of Iron.

When the wire of a closed homogeneous circuit is heated at some spot, a thermo-electric force is not set up. Even when there is a transformation point somewhere at which two allotropic phases are in contact, there need not be a thermo-electric current, because the potential differences at the surfaces of contact will balance one another. For in a thermo-couple, *e.g.*, of Le Chatelier, there is a hot junction between the wires of platinum and of platinum-rhodium, and there are two cold junctions (kept in ice) at the points where the free ends of the wires are soldered to the copper leads, whilst the temperatures will be equal at the contact surfaces of the transformation point. But there is a probability of such a thermo-electric effect, because every allotropic transformation requires some time to be established; this latter fact probably explains why the transformations generally are observed to take place at higher temperatures when the material is being heated than when it is cooling. Professor Trouton observed in 1886 that a thermo-current was flowing when an iron wire was being drawn through a Bunsen flame so that it became locally heated; in that case the two contact surfaces may differ in temperature, and an effect of thermo-electric hysteresis (the name was suggested by Sir W. Barrett) will be noticed. On these considerations Professor C. Benedicks, of Stockholm, has based a method of determining the critical points of iron which he described before the Iron and Steel Institute last May.* Modifying an arrangement proposed by H. Le Chatelier, he moved an iron wire at uniform speed through an electric furnace; any molecular transformations occurring at certain temperatures should set up thermo-electric currents. In this way he observed a marked discontinuity corresponding to the point A_3, but not any corresponding to A_2. The result has induced Messrs. G. K. Burgess and H. Scott, of the Bureau of Standards, to try another modification of Le Chatelier's arrangement, and they have communicated a first account of their experiments to the Paris Académie des Sciences (*Comptes Rendus*, July 10, 1916). An iron wire, 7 cm. long, 0.05 mm. in diameter, was stretched in a vacuum electric furnace; each end of the wire was soldered to the junction of a Le Chatelier couple. A galvanometer inserted between the two platinum wires measured the thermo-electric force of the couple iron-platinum for the temperature gradient in question; the two ends of the iron wire only differed in temperature by a few degrees Centigrade. The actual temperatures of the two ends of the iron wire were determined by the potentiometer method. A great many observations, both of heating and cooling curves, were taken at intervals of 2 deg. C., the moments of the observations being determined with the aid of a chronograph. The galvanometer was highly sensitive; but the description of the apparatus does not give any further details, referring back to a previous publication by Messrs. Burgess and Crowe. The iron was very pure, being of 99.968 per cent. and containing only 0.009 per cent. of carbon, the same amount of sulphur, and smaller amounts of copper, manganese, silicon and phosphorus. The curves mark both the A_3 and the A_2 points very clearly. While the temperature differences between the ends of the iron wire fluctuated between 3 and 5 deg. or between 7 and 12 deg. only, the thermo-electric force rose on heating and cooling to a humped peak and then fell off, gradually and then rapidly, a little above 900 deg. C. (on heating), or below that temperature (on cooling); that is the point A_3. The A_2 point was also distinct, but much more marked as a decided maximum on the heating curve than on the cooling curve; on the latter it was a point of inflexion at 768 deg C. rather than a maximum. The point A_1 was absent on

* Engineering, June 30, 1916, page 633.

both these curves, whilst it appeared clearly in an iron containing 0.1 per cent. of carbon. Further experiments with steels and at lower temperatures are to follow.

JAPANESE SHIPBUILDING AND SHIPPING SUBSIDIES.

The Japanese State subsidy system in regard to shipbuilding came into operation twenty years ago by the measure of 1896. It remained in force until 1910, and then it was only slightly modified. According to size, speed and the employment of Japanese materials ships are divided into four classes, and the State subsidy varies from 11 to 22 yen per ton. This has materially and steadily increased the building of merchant vessels at Japanese yards, and during the last ten years the three largest Japanese steamer companies have hardly ever bought or ordered vessels from foreign countries. The largest vessels hitherto built in Japan are three 13,500-ton boats for the Toyo Kisen Kaisha Company, which runs between Hong Kong and San Francisco. When shipbuilding subsidies came into force, State aid was granted to shipping. This Act was revised in 1909 for five years from the beginning of 1910, and again in 1915. The general State aid, available for all lines and vessels, was abandoned at the end of 1909, and only the following four lines received State subsidies, viz., those plying to Europe, North America, South America and Australia. A special subsidy has since been granted to the South Sea line. The conditions for State subsidy are that the steamers are built in Japan, are over 3,000 tons, not more than 15 years old, and possessed of a speed not less than 12 knots. The subsidy decreases from the sixth year of the steamer being put on service. The aggregate tonnage of the Japanese merchant navy was doubled from 1904 to 1914, the respective figures being :—

	1904. Tons.	1914. Tons.
Steamers...	798,240	1,577,025
Sailing vessels	329,125	513,244

The State subsidies for the year 1914 amounted to: shipbuilding subsidies, 1,630,000 yen ; shipping subsidies, 8,285,986 yen; besides 150,000 yen (£15,312) to the South Sea line. The subsidies for the different lines, according to the existing five years' measure, are as follow :—

—	Europe.	North America.	South America.	Australia.
	Yen	Yen	Yen	Yen
1914	3,105,106	4,377,009	576,772	227,099
1915	1,832,806	2,924,777	303,906	183,206
1916	1,811,910	2,949,012	297,558	173,808
1917	1,754,196	2,802,119	291,211	160,253
1918	1,689,805	2,669,925	284,863	169,740
1919	1,569,272	2,509,187	269,350	186,494

The latter five years mean a saving to the Japanese exchequer, compared with the period 1910–14, of 17,527,526 yen. The Japanese Government has acted upon the principle of gradually diminishing the subsidy and thereby obliging the shipowners to exert themselves. The war, of course, has brought great profits to Japanese shipping. The following figures illustrate the increased shipbuilding activity :

	No. of Vessels.	Tons.	State Subsidies. Yen.
1914 ...	15	58,000	1,630,000
1916 ...	30	130,000	3,120,000

For 1917 the State subsidy is expected to reach 6,000,000 yen, but a reduction is said to be under contemplation. Japanese shipping has gained much ground during the war. The Toyo Kisen Kaisha now controls the routes from Japan, Hong Kong and Manila to San Francisco and the West Coast of South America. The Nippon Yusen Kaisha controls the traffic between Japan and the ports of Puget Sound, and has a regular route from Japan *via* the Panama Canal to New York. Osaka Shosen Kaisha works the route from Japan and China to Canada and the route from San Francisco to Melbourne and Sydney. The Mitsui works a cargo trade from Japan to San Francisco. No less than 48 Japanese boats are regularly engaged in Japan–San Francisco trade. The Osaka Shosen Kaisha now has a fleet worth about 150,000,000 yen, (£12,312,000) and has started a new route between San Francisco and Australia with fast 20,000-ton boats, fitted with cold storage, &c.

THE GERMAN IRON AND STEEL INDUSTRY DURING THE WAR.

A SUMMARY survey of the German iron industry during the war, both as regards the financial results and the changes in the trend of the industrial developments, may be of some interest. It is claimed for the German iron industry, and not without cause, that it has acquitted itself well; even the year 1914–15, with all the transition work necessitated by taking up war manufacture and the many impediments ensuing from the war, gave satisfactory results, but 1915–16, with the war industry in full swing, has, as regards a number of leading concerns, even left the record year 1912–13 behind, as will appear from the following comparative table :—

—	1915–16. Gross Profits.	1915–16. Writings-off.	1915–16. Dividend.	1912–13. Gross Profits.	1912–13. Writings-off.	1912–13. Dividend.
	Marks.	Marks.	Per Cent.	Marks.	Marks.	Per Cent.
The Phœnix Company	46,700,000	13,900,000	20	42,000,000	16,500,000	18
Bochum Union	22,600,000	5,200,000	25	8,900,000	2,400,000	14
Rhenish Steel Works	12,200,000	7,200,000	10	11,500,000	6,300,000	10
The Hoesch Company	13,600,000	4,700,000	20	13,100,000	5,700,000	24
The German-Luxemburg Company	32,900,000	22,900,000	7	29,400,000	16,100,000	10
The Aumetz-Friede Company	16,600,000	6,500,000	10	15,900,000	4,800,000	12
The Van der Zypen Company	17,300,000	3,700,000	25	4,500,000	1,100,000	12
The Rombach Company	—	3,800,000	8	15,200,000	3,900,000	10
The Mannesmann Company	31,800,000	3,800,000	15	15,800,000	2,800,000	13½
The Gelsenkirchen Cast-Steel Company	6,000,000	1,500,000	25	1,100,000	200,000	6
The Witten Cast-Steel Works	6,000,000	1,200,000	27	2,700,000	600,000	14
The Hasper Iron Works	7,700,000	2,900,000	16	4,500,000	1,300,000	12
The Charlotte Hütte	3,200,000	1,500,000	16	2,500,000	700,000	16
The Lübeck Blast-furnace Company	4,200,000	1,300,000	10	2,100,000	1,000,000	5
The Laura Hütte	13,600,000	6,000,000	10	13,500,000	6,500,000	8
The Bismarck Hütte	11,800,000	4,800,000	25	4,100,000	2,500,000	9

This eminently satisfactory list, from the shareholders' point of view, is even better than appears from the quoted figures, inasmuch as war-tax reserves have been provided for beforehand in several cases. The output is increasing, amounting on the average to 75–80 per cent. of peace production, against 60–65 per cent. for 1914–15. A few figures connected with the production of some leading works will illustrate this. The figures apply to the production of iron ore, of pig-iron and steel. The Hoesch Iron Works have only had their own mines for a few years, and for the Laura Hütte 1913–14 has been chosen as the best year so far :—

—	Iron Ore. 1915–16.	Iron Ore. 1912–13.	Pig-iron. 1915–16.	Pig-iron. 1912–13.	Steel. 1915–16.	Steel. 1912–13.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
The Phœnix Company	1,202,000	1,528,000	717,000	1,238,000	1,230,000	1,482,000
Rhenish Steel Works	395,000	472,000	435,000	595,000	500,000	689,000
The Aumetz-Friede Company	1,335,000	2,171,000	533,000	675,900	452,000	555,000
The Van der Zypen Company	336,000	353,000	123,000	129,000	173,000	131,000
The Hoesch Company	231,000	—	382,000	463,000	438,000	612,000
The Hasper Iron Works	—	—	202,000	291,000	198,000	224,000
The Laura Hütte	38,000	37,000	162,000	251,000	254,000	320,000

The 254,000 tons of the Laura Hütte were rolled iron.

Concerning production, the Van der Zypen Steel Works held an exceptionally favourable position by being able to keep up their output of iron ore very nearly to the peace level and also their production of pig, by using the less valuable ores, and they even increased their output of steel beyond that of the record year 1912–13. Other works could not even approach this production as regards quantity. They kept up the aggregate value of their output by higher prices. It was only towards the end of the business year 1915–16 that serious endeavours were made to stop the rise in prices, and even then they did not take general effect.

The following table shows the movement of prices during the war as far as some leading commodities are concerned :—

—	Ore.	Pig, Middling Quality.	Billets.	Shaped Iron.	Bar Iron.
	Marks per Ton.	Marks per Ton.	Marks per Ton.	Marks per Ton.	Marks per Ton.
3rd quarter, 1914 ..	12.60	60	82½	110	94–97
4th quarter, 1914 ..	12.80	74	90	110	94–97
1st quarter, 1915 ..	12.80	74	90	110	94–97
2nd quarter, 1915 ..	14.20	81	97½	120	135–140
3rd quarter, 1915 ..	15.60	88½	102½	130	140–145
4th quarter, 1915 ..	16.30	88½	102½	130	140–155
1st quarter, 1916 ..	16.30	88½	102½	140	140–160
2nd quarter, 1916 ..	17	93½	107½	140	180–195

It will appear from this table that the prices for the raw commodities, ore, pig and steel, rose considerably more moderately than did those for more finished articles, for instance, bars, plates and other rolled products, which latter goods closely follow bar iron in the matter of price movements. The most important rise in the quotations for steel (for instance, 20 marks per ton for all kinds) has only taken effect after the end of the business year 1915–16. Notwithstanding this fact most of the works showed brilliant balance-sheets for the year. It must be remembered that the large works, on an increasing scale, themselves further handle the intermediate products, so that the sale of the Steel Union during the year 1915–16 only amounted to 3,200,000 tons out of an aggregate steel production of 14,750,000 tons. This fact accounts for the most satisfactory results of last year in spite of the inadequate prices prevailing for raw and half-finished goods.

The finishing processes adopted during 1915–16 did not only move in the grooves prevailing in periods of peace, but in many instances they followed new lines and meant new departures. Whilst in times of peace the further processes result in the production of B products, that is prominently bar-iron, rolled wire, plates, and, only on a small scale, machinery, constructive parts, &c., the works have succeeded during the war in shifting the balance from the sale of rolled goods to the manufacture of actual articles of consumption, especially in the shape of war material, munitions, barrels for rifles, gun carriages, barbed wire and other highly remunerative articles which were manufactured in large quantities by the iron works in their own works. And even if the army department apparently has succeeded in somewhat reducing the prices during the second year of the war for the necessary direct war requisites, the road from raw products to the finished article still left an ample margin for profits. This becomes particularly apparent at works which also in times of peace produce such qualities, which are specially adapted for war purposes. The Bochum Cast Steel Union may be taken as an example of how the value of their goods has risen during the war, as the appended table will show :—

	Sale in Tons.	Value. Marks.
1912–13	312,931	52,191,720
1913–14	334,202	56,781,428
1914–15	217,105	54,722,688
1915–16	247,197	112,309,912

These figures show a material reduction in quantity ; notwithstanding this the value of the sales has been more than doubled in 1915–16 as compared with the otherwise very favourable year of 1912–13. This is owing not so much to higher prices in general as to the fact that the products were carried to a much higher degree of finish. The sale of pig and raw steel was comparatively small, that of by-products and cast steel goods, on the other hand, much higher. The same results occurred at other undertakings which make cast steel a speciality, such as the Gelsenkirchen Cast Steel Works, the Witten Cast Steel Works, &c., as well as those concerns that make quality steel of special kinds, such as the Becker Steel Works, the Richard Lindenberg Steel Works, &c.

The fact that quality is so essential in the manufacture of all war material has not only enhanced the chances of such concerns which in times of peace went in for quality, but encouraged them to further effort. A number of other undertakings have also

in a marked manner gone in for quality products during the war. It goes without saying that large mixed concerns as the Phœnix Company and the Laura Hütte cannot undertake fine work to such an extent as others, on account of the bulk and the breadth of their manufacture and the complete alteration of the basis which a comprehensive change would entail. Still, such undertakings, too, have exerted themselves to raise the quality of their products, and with good results. This will appear from the following table, showing the trend of production of Thomas steel (average quality) and of Siemens-Martin steel (special quality) of the Phœnix Company during the last four years:—

	Thomas.	Siemens-Martin.
	Tons.	Tons.
1912–13	844,615	631,067
1913–14	828,517	667,480
1914–15	586,700	506,368
1915–16	633,002	594,855

Whilst the production of Thomas steel in the second year of the war was about 75 per cent. of that of the preceding years of peace, the production of Siemens-Martin steel has almost reached the figure of normal years. This state of affairs is typical of the whole of the German iron industry, especially the Rhenish-Westphalian and also the Upper Silesian. The reason for this movement is partly the extra 20 marks per ton which Siemens-Martin steel fetches, compared with Thomas steel, and partly because new plant on the former system is easier to instal.

Those works which can handle high-class Siegerland or Hesse-Nassau ores are in a position to derive greater advantages from the demand for quality iron than such works which have to fall back upon less valuable ores. This, for instance, applies to the works within Lorraine-Luxemburg district, whose results during the second year of the war at the highest can be called satisfactory, but by no means brilliant. No doubt the fact of these works being so near the scenes of the war and partly having to lie idle during the first year of the war has to bear part of the blame for this.

The Rupture of the Weisse Desse Dam in Bohemia.—The failure of the dam which crosses the valley of the Weisse Desse, on September 18 last, caused some commotion also in Switzerland, where similar dams have been constructed, but seems to have been due to faulty design and construction. The dam closed the smaller of two basins in the district on a length of 243.5 m. and a height of 14.45 m., being 4.0 m. wide at the crown and about 45 m. wide at the bottom. The batter on the water side was 1 in 2 or 1 in 1½. The foundations were secured by means of sheet piling, ribs of concrete, and a strip of puddled loam, 3 m. in width. The body of the dam was formed of loamy ground taken on the site, the layers, of 40 cm. depth, being compressed to 30 cm. by means of petrol-driven rollers. This work, we see from the *Schweizerische Bauzeitung* of November 18, which quotes the Government engineer, E. Grohmann, writing in the Vienna journal *Wasserwirtschaft*, was not properly done, and there were faults in the design and embedding of the pipe conduit. The incline of the bottom of the valley above the dam was 20 per thousand, but the gradient rose to 40 and 60 per thousand below the dam; and the loam could not be expected to keep watertight. Considerable damage was done, but loss of life is not mentioned.

The P. and O.—The directors of the Peninsular and Oriental Steam Navigation Company announce a very remarkable fact, viz., the reduction of the company's fleet by nine steamers during the past year. Of these steamers four were appropriated by the Government, and only five have been actually lost; two were sunk by enemy submarines in the Mediterranean, and one was destroyed by an enemy mine off Dover. The loss of these vessels has been severely felt by the company. Two mail steamers, which have been under construction for some time, have made certain progress, as well as two large vessels with refrigerators, which were ordered early in 1916; construction, however, has been greatly delayed owing to the requirements of the Admiralty. When there is a prospect of delivery being obtained the company proposes to order several more ships. The acquisition by the P. and O. of a controlling interest in the New Zealand Shipping Company, Limited, has now been completed. The acquisition will enable the company to keep *au courant* with life and business at the Antipodes. Notwithstanding the—at any rate—temporary reduction of the fleet, the company's ships, stores, freehold and other property, workshops, machinery, wharves, moorings, &c., stood in the books at the close of September, at 12,401,009*l.* The company had raised, at the same date, 5,743,694*l.* by issues of preferred and deferred stocks. The amount of the preferred stock in circulation is 3,040,000*l.*, and that of the deferred stock 2,703,694*l.* The company had also raised, at the same date, 1,700,000*l.* by 3½ per cent. debenture stock, and its reserve fund amounted to 1,500,000*l.* It had, also, at the same date, a contingent fund of 450,000*l.*, and a provident good service fund of 150,000*l.* One result of the past year's working was an addition of 126,000*l.* to the reserve fund, the profits for the twelve months having been 654,463*l.* The balance brought into the past year's working was 78,182*l.*, and the corresponding balance carried to the credit of 1916–17 was 85,329*l.*

GOVERNMENT APPOINTMENTS FOR ENGINEERS.

To the Editor of Engineering.

Sir,—I have been requested by a Government Department to receive applications from a number of assistant engineers who would be willing to undertake work as salaried and wholetime officers.

It is desirable that candidates for these posts should not only be well qualified, but experienced in the values of machinery and questions of depreciation of machinery.

I know that many members of the engineering institutions, who are above military age or otherwise incapable of giving military service, are anxious to serve their country in a capacity in which their professional experience may be of value.

The salaries for the positions in question range from about 250*l.* to 400*l.* per year.

Applications should state the age of the candidate, and, if he is of military age, why he is not in military service, and should give details of the candidate's qualifications, past training, and experience, and should be sent to the address below marked "Private."

Suitable candidates will be interviewed by Captain H. Riall Sankey, C.B., R.E., and Mr. Charles L. Morgan, M.Inst.C.E., and will receive a communication on the subject of an interview in due course.

I am, Sir, your obedient servant,

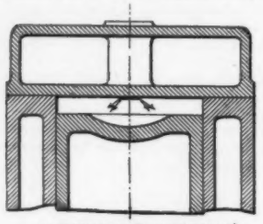
W. C. Unwin, *President.*

The Institution of Mechanical Engineers, Westminster, London, S.W., December 1st, 1916.

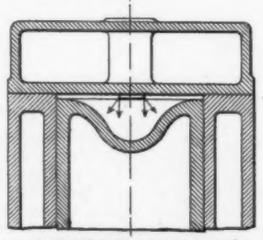
TESTS ON A DIESEL ENGINE.

To the Editor of Engineering.

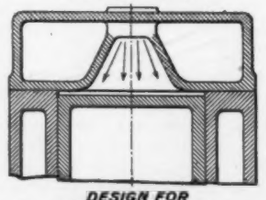
Sir,—In reference to the letter in your issue of November 24, page 515, on the experiments carried out by the late Lieutenant Wilkins on the Diesel engine, at the Birmingham University, Mr. Mickelsen assumes that the fuel valve was improperly set, as any further injection of oil than would produce a mean pressure of 86 lb. per square inch resulted in a smoky exhaust. In all probability the inability completely to consume any more fuel and the marked "afterburning" effects shown are due to unsuitable shape of combustion space. Being a



BURMEISTER AND WAIN'S ORIGINAL DESIGN.



BURMEISTER AND WAIN'S PRESENT DESIGN.



DESIGN FOR 2 STROKE ENGINE.

four-stroke engine, the bottom of the cylinder cover will be flat, and as the engine is of antediluvian pattern the top of the piston will probably be flat also.

The combustion space will be, therefore, shaped like a disc 6½ in. diameter and 1 in. deep. The fuel is injected into the centre of this disc, and it is easy to see the difficulty of the fuel and the air getting together during the short injection period.

In the development of the idea of a suitable shape of combustion space the designs of Burmeister and Wain are instructive. Their original design had a slight dishing downwards of the piston top and a fuel valve opening inwardly, as indicated in the sketch herewith. The inwardly opening fuel valve, of course, tended to throw the fuel out circumferentially. In their latest design the piston is deeply recessed in the centre, as shown by the sketch. The fuel is thus injected into a deep body of air, and will not be thrown in an unburnt state on the piston. This last design is a great improvement on the first, but it is, so to speak, upside down.

The piston top should be flat, so that the cooling water can be taken away by one central pipe and the recess should be in the form of a cone in the cylinder cover, with the fuel valve at the apex of the cone, as indicated by the third sketch. The fuel is thus passed first through a layer of exhaust gases left from the last stroke and made extra hot by the compression, thus thoroughly vaporising the fuel before it reaches the air. The conical shape is the natural form taken by the injected fuel, which will not, therefore, impinge on the cold surfaces of the metal. This principle of the injection of the fuel into a long length of air is carried out in the horizontal type of Diesel engine.

Unfortunately Professor Burstall is not the only Britisher who does not believe in the "future" of the Diesel engine. A visit to some of the Continental works (after the war) would perhaps open his eyes as to the very substantial "present" of the Diesel engine.

Yours faithfully,

W. R. Cummins.

2, Rosmead-road, North Kensington, London, W.

To the Editor of Engineering.

Sir,—My attention has been drawn to a letter from Mr. Mickelsen, on page 515 of your issue of November 24th, dealing with the trials made on a Diesel engine by the late Lieut. Wilkins, for whom I acted at the Institution of Mechanical Engineers, and I feel I cannot let this letter pass owing to the misstatements it contains as regards my late pupil, whose death in action makes it necessary for me to defend his work.

Mr. Mickelsen implies that the whole of the engineering staff at the Birmingham University are grossly ignorant of how to set the valves of a Diesel engine, and that had we called in the maker the results of Lieut. Wilkins's paper would have been quite different. May I inform him that before these experiments were made, and for some years after, Lieut. Wilkins was engaged in the Diesel department of Messrs. Vickers, of Barrow, and that he therefore presumably knew when these valves were in order. In the next place, this particular experimental engine was built by the Maschinenfabrik Augsburg, and after it was installed at Birmingham a representative of the Diesel Company spent quite a considerable time here to make sure that the engine was what they wished it to be. As to the correctness of the paper, I have not had access to Lieut. Wilkins's log sheets and working, but I know him to have been extremely particular as to the accuracy of his results, and I feel quite certain that, as far as he is concerned, the figures are exactly as they were obtained on test.

I am sorry that I personally appear to have offended those who can only see in the Diesel engine the motor of the future. I shall not attempt to defend myself beyond saying that any remarks that I make in public on the subject of internal combustion engines are the result not merely of a fairly extensive laboratory study of these motors, but from what I see of their behaviour in commercial conditions, and if Mr. Mickelsen will keep his eyes open to other possible heat motors he may learn a good deal which at present he does not anticipate.

Yours truly,

F. W. Burstall.

University Power Station, Edgbaston, Birmingham, December 4, 1916.

ELECTRON, QUANTA AND RELATIVITY THEORIES.

To the Editor of Engineering.

Sir,—If I understand "Sesamy" aright, he holds that there is no truth in either the electron, the quantum, or the relativity theories. It is therefore useless to prove to him even, by the aid of a diagram, that the opposing theories of the electron and the quantum can be reconciled, that the Stark effect and spectral series can both be given a sound physical interpretation, and that Maxwell's electromagnetic theory of light must be modified to include both the electron and the quantum in accordance with the diagram.

But I am otherwise in complete agreement with him in his attitude towards the modern schoolmen, who completely outclassed the schoolmen of the Middle Ages when they placed 1,700 electrons inside one atom of hydrogen. To-day one electron only remains, and even that is missing when the hydrogen atom is positively charged. But they are still determined to place inside the atom an electric image of the forces really due to the surrounding medium. Just as the most deadly poisons are vegetable bases akin to food-stuffs, so the electron theory contains sufficient truth to poison science at its source. Maxwell warned us in his preface as follows:—"Great progress has been made in electrical science, chiefly in Germany, by cultivators of the theory of action at a distance. The great success which these eminent men have attained in the application of mathematics to electrical phenomena gives, as is natural, additional weight to their theoretical speculations, so that those who, as students of electricity, turn to them as the greatest authorities in mathematical electricity, would probably imbibe, along with their mathematical methods, their physical hypotheses." Mathematicians of to-day are like moles, each in his own little burrow finding his way about apparently by a sixth sense and turning up symmetrical rubbish heaps—a useful servant but a very bad master. We have no mathematicians of the type of Maxwell or Rankine, with views wide enough to co-ordinate all the known facts of physics. The amateur to-day is plainly told that there is no place for him; and that engineers have ceased to discuss these

questions is shown by their non-contribution to this discussion.

Sir J. J. Thomson discovered that lines of force have inertia, and ascribed that inertia to electricity, where both Maxwell and Faraday would have ascribed it to the medium and at once have developed their dynamical theories. What a different meaning this gives to Thomson's words :—"The additional momentum $\frac{2}{3}\frac{u}{a}\frac{e^2}{}v$ is not in the sphere, but in the space surrounding the sphere. There is in this space *ordinary mechanical momentum*, whose resultant is $\frac{2}{3}\frac{u}{a}\frac{e^2}{}v$ and whose direction is parallel to the direction of motion of the sphere. It is important to bear in mind that this momentum is not in any way different from ordinary mechanical momentum, and can be given up to or taken from the momentum of moving bodies. I want to bring the existence of this momentum before you as vividly and forcibly as I can, because the recognition of it makes the behaviour of the electric field entirely analogous to that of a mechanical system." . . . "Many of you will notice that the momentum is parallel to what is known as Poynting's vector—the vector whose direction gives the direction in which energy is flowing through the field."

The theory of relativity is at present stated in a form repugnant to common-sense; but given a material atomic ether, a solar vortex with planetary sub-vortices is a necessary consequence; and the interaction of the two plena of these vortices would doubtless be sufficient to affect the direction if not the apparent velocity of light. Also if the momentum is confined to one plenum, as suggested by the work of Osborne Reynolds, and consequently towards the centre of the relative vortex, then Poynting's energy vector, generated by atomic readjustment inversely proportional to the square of the radius, becomes identified with gravity.

FRED. G. EDWARDS.

33, St. Ronans-road, Sheffield, December 2, 1916.

"SPARK IGNITION."

TO THE EDITOR OF ENGINEERING.

SIR,—The investigations of Mr. J. D. Morgan on "spark ignition," interesting though they be, seem to be non-conclusive. The term "incendivity" is objectionable in that, as the writer himself admits, the ability of producing an ignition varies with the consistency of the gas, *i.e.*, a spark of a given "incendivity" will ignite a good mixture but not a poor one; I do not think it good practice to express in a single term two variable factors.

It is bewildering to hear that: "The first is that incendivity does not depend upon heat alone, but apparently on heat jointly with temperature." "Heat" and "temperature" are synonymous terms, are they not?

For some years past I have made experiments, with the ultimate outcome that I have finally succeeded in starting the four-stroke cycle engine while cold "on the crank" on kerosene (paraffin), using the conventional sparking plug, with spark coil and battery.

All my experiments were made under actual working conditions and the fuels used: Gasolene (petrol), kerosene (paraffin), various crude oils (Pennsylvania, Mexico, California), gas oil, drip oil (condensations from the pipes of illuminating gas) and tar. Tar oils were not available, but fish oil, peanut oil, benzol and alcohol were also used as fuel.

I have used spark coils up to 3 in., also condensers variously connected, only to find that the coil best suited was the conventional ¾-in. coil with a very fast vibrator (made by Carpentière in Paris).

I have spoken of the "heat release" at the sparking points, perhaps not a happy term, but serving to indicate that the heat, as converted from electrical energy released at the points, is the thing that counts.

Although the 3-in. coil produced the greater heat release per spark, its cumulative effect was nil on account of the time element involved in a fast-running engine; the vibrator producing but one beat, being too sluggish on account of its size, and the electrical induction phenomena were also too slow on account of its size. The cumulative effect of the vibratory swings of the trembler and its inductive phenomena, the large "heat release" resulting, may perhaps be produced in another manner: a hot wire device, say; this would require at the least 200 amperes and would be of somewhat difficult attainment for commercial reasons.

The sparking plug could be replaced by an "arc lamp" (a device similar in design to street lamps and of similar large dimensions). This, too, would involve questions of design and selling, which may prove prohibitive.

A "perfect" gas almost any sort of a spark will ignite—a well-known fact. Rarely in practice such perfect gas is encountered; why, then, consider the academical? Inquiry among many repair men shows that many a car that would not operate well with 6 volts at the coils would do so with 12. A "bomb calorimeter" experiment is one thing, an engine in a car another, and it is wholly unsafe to make deductions from the first to the second. My trials seem to indicate that the consistency of the gas within the cylinder of an engine varies continually.

The greatest variations of a detrimental nature are caused by the exhaust gases from the previous explosion. The consistency of the gases at the sparking points can but be guessed at, therefore, and since they may be either good or poor, it becomes necessary to use at all times sufficient "heat release" to fire even the very poorest charge.

I have overcome this difficult situation by arranging for the absolute absence of exhaust gases in the vicinity of the sparking points. More: I provided that the cumulative effect of the heat release could not produce an ignition, but would produce a "local heat zone" in which a slow burning without ignition proper could be maintained, and that for starting purposes (on kerosene—paraffin). The explosion proper is then produced by adding air at the right time, which is done by the ingoing piston during the compression stroke. When so arranged, the engine will start cold.

When conventionally fitted with magneto and spark coils the engine cannot be started when the air enters without preheating, and cannot be started although the engine is quite hot (650 deg. F. in the "jacket"). Once started, and when warm, such engine will function properly, however.

At this writing I cannot assign any reason why it should be more difficult to get an engine under way when cold than warm. Granted that a portion of the gas will condense on the too-cool walls of the cylinder; what about the remainder, the major portion?

The much-spoken-of "turbulence" of the gases can be but inconsequential under compression (full compression), so that an uncontaminated "core" should be present, a central portion of good gas. Assuming that the sparking plug of a "T" head motor was too remotely placed from this "core," the "I" head motor should then not suffer from a like shortcoming.

Are the "L" head motors known to be less troublesome to start while cold? If such were the case, its advocates would have made much of this in the past. Seemingly the right answer does not lie there. If the warmth of a cylinder acts to better the ignition, the ease of starting—as seems to be the case—what is the reason?

But one or two explosions are sufficient in my case to reduce from a "long" spark to the conventional "short" spark; that so, is there a "skin effect" in the metals of the engine? Such effect might then be either in the metal itself and acting directly upon the gases; or a "zone" may be formed in its proximity, and this of a character as observed in electrical currents, "alternating" or "pulsating." Is it not claimed there that such currents flow rather outside of the wire and in the skin?—when it is stated that "direct" current, a flow of a non-fluctuating character, flows through the entire cross-section.

Although several thousand trials were made before I was able to start cold on crude oil (Pennsylvania)—a method I have used for several years to the exclusion of gasolene (petrol)—I found it much more difficult to start from cold on kerosene (paraffin). I then evolved the theory that I was using but the most volatile portions of the fuel; I used a large amount of crude to start and threw out the balance.

Plausible though this was, and perhaps correct, the fact that the same procedure permitted the starting from cold on kerosene (paraffin) cast a doubt upon the former conclusion. Was not all the volatile matter removed from the fuel by distillation?

I would rather form a conclusion, and be proven ultimately wrong, than not form any conclusion at all. I cannot subscribe to the sneer given vent to elsewhere in the proceedings of a society, as printed in your paper, about the men who have no reputation to lose—a man who guards his reputation by much caution is both poverty-stricken and a coward. In this case I have formed a conclusion, but will not give it here, and leave it an open question.

That the presence of exhaust gases near the sparking points plays an important rôle may easily be verified when studying the phenomena of "hot-tube" ignition. An engine so equipped will "six-cycle" when lightly loaded and the tube not hot enough; a two-stroke cycle engine will "four-cycle"; the "miss" will permit better gas in the "hot tube."

The "shot channel" once widely used in connection with the hot tube was abandoned finally because it lost its virtue under a variable load: the exhaust gases would foul the channel (it had been found that in the "shot channel" a flame would be formed which would strike out powerfully into the cylinder proper, giving a more complete combustion than the hot tube alone).

The well-known fact that any four-stroke cycle gasolene engine will operate on kerosene (paraffin) under full-load conditions, when the engine is already well heated, and the further fact that the same engine will not function properly under reduced load, plainly brings the kerosene (paraffin) burning to its finality—a heat problem.

In conversation with the manager of a large boat-engine building concern I was told: "We burn kerosene (paraffin) perfectly in our engines." After I brought a little pressure to bear he admitted that such was the case only under full load, that no satisfactory service was obtained by their engines under reduced loads.

Two interfering items are, therefore, in evidence—the presence of exhaust gases near the ignition means and the lack of heat. The former can be overcome as outlined in the foregoing. The latter by raising the heat of the engine all around, and that at least to such an extent that the minimum heat of the engine under idling conditions is at least as high as the heat of the engine under full load.

This involves several interesting questions: The heat must be still higher than the "air-cooled engine." Those engines barely passing by on the lubricating question would rather deny the possibility of raising the cylinder temperature still further, *i.e.*, cylinder oiling trouble should set in. Secondly, it is claimed in many quarters that the sparking plugs have reached the limit of heat endurance, and higher temperatures will be out of question on that count alone. Thirdly, with a hot cylinder the volumetric efficiency is bound to fall off to such an extent that all possible gain will be thus offset. Fourthly, that to get the exhaust valves right has taken a very large amount of earnest work, and that under higher temperature conditions warped and pitted valves will make illusory any gain made in the higher heat direction.

In favour of higher heat operation it may be said that the range of speed and load becomes then satisfactory. That the formation of carbon is less on account of the hotter surfaces. That the exhaust valve will be free from carbon deposit on account of its higher heat. That the volumetric efficiency will not be affected perceptibly by the increase in temperature, gas being a very poor conductor of heat; but those portions in close proximity to the hot metal walls will be expanded to a greater extent (this would call, then, for a most compact combustion chamber design—the "I" head; it would call also for a spherical construction of the "combustion chamber" at the time of the innermost piston position). That with higher mean temperatures in the metals the fuel efficiency will be greater.

All this tends to show that the high temperature engine is desirable; the question remaining open: Can an oil film be provided to withstand the higher temperatures?

Yours very truly,

P. G. TISMER.

New York, November 16, 1916.

PROGRESS WITH THE INTERNAL COMBUSTION ENGINE.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with very much interest the article under the above heading in your issue of December 1, in connection with the paper given by Dr. Dugald Clerk at the Royal Society of Arts. There is, however, an important omission which may lead those who are not fully acquainted with the whole of the facts to form a wrong conclusion with respect to my father's (James Robson's) 1877 patent for his "two-cycle" *compression* gas engine, and I should like the opportunity of setting this right.

On page 534, column 2, line 35, it states: "Mr. Robson's first patent was dated 1877, No. 2334. It describes an engine of the *non-compression* type."

The important omission to which I refer consists in the fact that this statement is only partially correct, as while the Patent Specification No. 2334/1877 makes a minor reference in Fig. 16 to a non-compression engine (which is not claimed), *the first and main claim* in this patent is for his original "two-cycle" *compression* gas engine, described by Figs. 1 to 3 of the specification.

This patent No. 2334 of 1877, described for the first time in history, a *compression explosive* gas engine in which the front end of a piston working in a single cylinder is used as the gas and air pump, and the opposite end as the motive power side, and it therefore constituted a "master" patent. My father's 1879 patent, No. 4501, to which Dr. Clerk also refers, was for an improvement of the original 1877 patent two-cycle *compression* gas engine.

My father was not a wealthy man, neither did he receive any monetary assistance from others, and as the cost of a patent in those days was rather serious, he had to construct and perfect his inventions before going to the expense of a patent.

It will therefore be of interest to your readers to know that my father made and put to work his 1877 two-cycle *compression* gas engine months previously to protecting it by patent. In this engine the charges of gas and air were *compressed* by the engine piston to between 30 and 35 lb. before ignition. This engine was in operation in the early part of 1877 driving a 10-in. self-acting lathe and other machine tools in my father's experimental workshop, where it remained in regular use until he commenced to work in 1878 upon his improved 1879 patent gas engine.

Full particulars are given in the booklet recently published by me (and referred to in your article) of my father's 1877 two-cycle compression gas engine.

My father also protected his 1877 two-cycle compression gas engine in Germany and the United States of America, and in accordance with the regulations in those countries it was subjected to a most critical examination before being accepted by the respective patent office officials.

It is obvious, therefore, that this two-cycle *compression* gas engine was made and put to actual work by my father in the early part of the year 1877, and that it was of sufficient size to be capable of driving the machine tools in his experimental workshop. This engine was seen at work by many of my father's friends in the North of England, and the writer as a boy used to render assistance to him in connection with his experiments on this engine, and in helping to pull it round when it was being started.

I must apologise for taking up so much space of your valuable journal, but if this omission is not properly rectified, and my father's undoubted rights acknowledged now, it may not be such a simple matter to obtain acknowledgment later on.

Yours truly,

JAMES ROBSON.

"Pendennis," Sandwell-road, Handsworth, Birmingham, December 5, 1916.

CUTLERY.—Our exports of cutlery are still well maintained. The shipments for October were 3,000 cwt., as compared with 2,895 cwt. in October, 1915, and 2,660 cwt. in October, 1914. The principal deliveries were made to the United States, South Africa, British India, Australia, New Zealand and Canada. The aggregate exports to October 31 this year were 28,572 cwt., as compared with 26,113 cwt. in the first 10 months of 1915, and 34,732 cwt. in the first 10 months of 1914. The United States took 1,393 cwt. of British cutlery in the first 10 months of this year, as compared with 2,464 cwt. and 3,984 cwt. respectively.

AN IMPERIAL TRUST FOR RESEARCH.

The Government have decided to establish a separate Department of Scientific and Industrial Research for Great Britain and Ireland under the Lord President of the Council, with the President of the Board of Education as vice-president. They have also decided, subject to the consent of Parliament, to place a large sum of money at the disposal of the new department, to be used as a fund for the conduct of research for the benefit of the national industries on a co-operative basis.

The Board of Inland Revenue have decided, with the approval of the Chancellor of the Exchequer, that no objection shall be offered by their surveyors of taxes to the allowance as a working expense, for income-tax purposes, of contributions by traders to industrial associations which may be formed for the sole purpose of scientific research for the benefit of the various trades; and the allowance would be equally applicable as regards traders' contributions specifically ear-marked to the sole purpose of the research section of an adapted existing association. In both cases the allowance would be subject to certain conditions; for example, the association or the research section to be under Government supervision, and the trader's contribution to be an out-and-out payment, made from his trade profits and giving him no proprietary interest in the property of the association, &c.

In order to enable the department to hold the new fund and any other money or property for research purposes, a Royal Charter has been granted to the official members of the Committee of the Privy Council for Scientific and Industrial Research under the title of the "Imperial Trust for the Encouragement of Scientific and Industrial Research." The trust is empowered "to accept, hold and dispose of money or other personal property in furtherance of the objects for which it has been established, including sums voted by Parliament to that end." The trust can take and hold land, and can "accept any trusts, whether subject to special conditions or not, in furtherance of the said objects."

A substantial gift has already been made to the trust by two members of the Institution of Mechanical Engineers for the conduct of a research in mechanical engineering to be approved by the department, in the hope that this example will be followed by other members of the Institution.

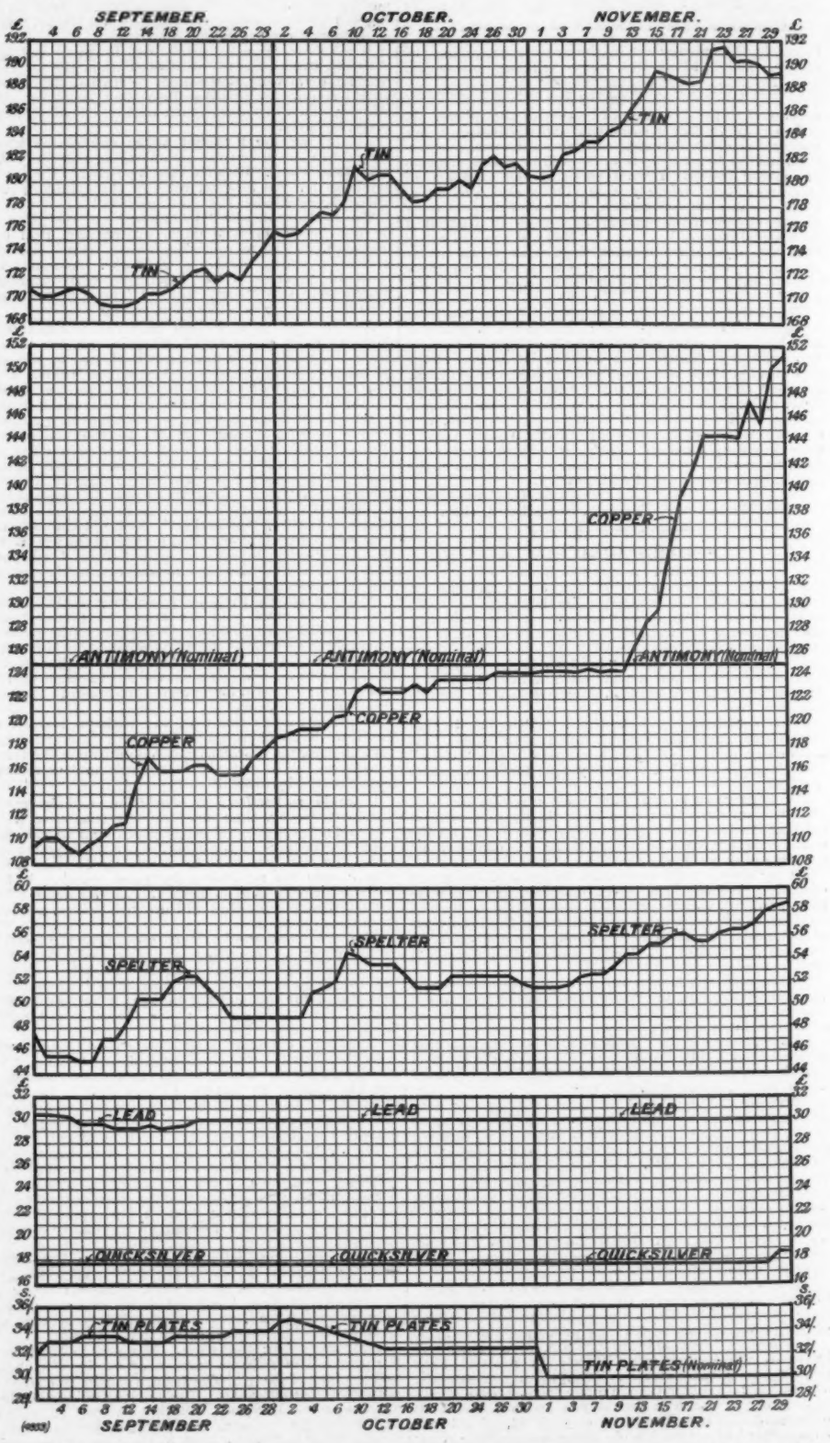
Mr. H. Frank Heath, C.B., has been appointed permanent secretary of the new department, and until December 31 all correspondence should be addressed to him at the offices of the Board of Education, Whitehall. On and after January 1 all correspondence should be addressed to: The Secretary, Department of Scientific and Industrial Research, Great George-street, Westminster, S.W.

Passenger Locomotive for the Caledonian Railway: Errata.—We regret to find that in the description of the new type of passenger locomotive for the Caledonian Railway, given on page 500 of our issue of November 24, the following typographical errors occur:—In the tabular statement of the chief particulars of these engines, the diameter of the tender wheels is given as 4 ft. 6 in., instead of 4 ft.; in the second line below the tabular statement the stroke of pistons (correctly given elsewhere) is given as 28 in. instead of 26 in.: and in the fifth line from the bottom of the first column of the page named the side play of the bogie is stated to be 2¼ in., instead of 2¾ in.

Royal Institution.—The ninety-first illustrated Christmas course of juvenile lectures, founded at the Royal Institution in 1826 by Michael Faraday, will be delivered this year by Professor Arthur Keith, M.D., F.R.C.S., LL.D., F.R.S., his title being "The Human Machine which All Must Work." The subjects are as follow:—Living Engines, December 28; Living Levers, December 30; Living Pumps, January 2; Living Bellows, January 4; Living Workshops, January 6; Living Central Exchanges and Wires, January 9. The lecture hour is 3 o'clock. The following are the lecture arrangements before Easter:—Professor C. S. Sherrington, six lectures on "The Old Brain and the New Brain and their Meaning, and Pain and its Nervous Basis." Professor W. E. Dalby, two lectures on "The Structure of Metals." Professor J. W. Gregory, three lectures on "Geological War Problems." Professor Sir Walter Raleigh, two lectures on "The Strength and Weakness of Romantic Poetry." Professor F. G. Donnan, three lectures on "The Mechanism of Chemical Change." Two lectures by Professor Edward S. Prior. Professor A. Dendy, two lectures on "Sponges: A Study in Evolutionary Biology." Professor J. A. Fleming, two lectures on "Modern Improvements in Telegraphy and Telephony": 1, Telegraphy; 2, Telephony. Arthur R. Hinks, two lectures on "The Lakes and Mountains of Central Africa." Dr. H. Walford Davies, three lectures on "Line and Colour in Music": 1, Piano; 2, String; 3, Voices. Daniel Jones, two lectures on "The Science of Speech": 1, the Pronunciation of Languages in general; 2, the Pronunciation of English at the time of Shakespeare. Dr. C. W. Saleeby, two lectures on "Imperial Eugenics. Stephen Graham, two lectures on "Russian Idealism": 1, the Russian Madonna; 2, the Ideas of the Russian Philosopher Vladimir Solovyof. The Friday evening meetings will commence on January 19, when Professor Sir James Dewar will deliver a discourse on "Soap Bubbles of Long Duration." Succeeding discourses will probably be given by Professor Gilbert Murray, Charles C. Carpenter, Daniel Jones, Rev. H. Hensley Henson, H. Wickham Steed, Charles F. Cross, Sir Almroth Wright, Sir J. Stirling Maxwell, Edward Clodd, and other gentlemen.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

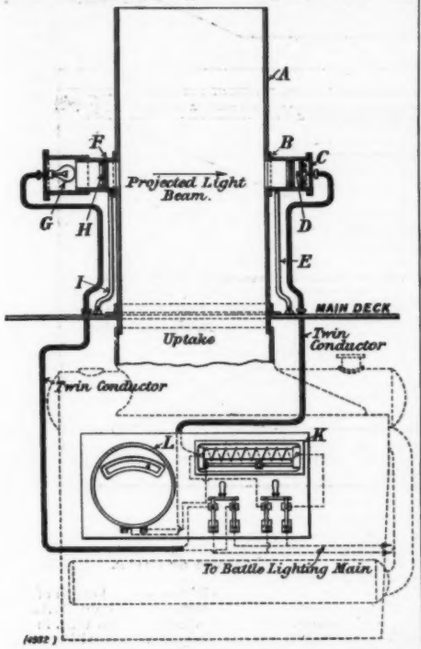
(Specially Compiled from Official Reports of London Metal and Scotch Pig-Iron Warrant Markets.)



Note.—In the diagrams above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for "fine foreign" and "standard" metal respectively. The prices shown for antimony and lead are for English metal in both cases, whilst those for spelter are for American metal. The prices are per ton, but in the case of quicksilver, however, the price is per bottle, the contents of which weigh about 80 lb.; the price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7 the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45 *ante*.)

INSTRUMENT FOR INDICATING THE DENSITY OF SMOKE IN UPTAKES.

THE annexed illustration shows an instrument installed upon the United States steamer Conyngham for the purpose of indicating in the stokehold the density of the smoke in the uptake. At each side of the funnel A there is fixed a cast-metal box, F and B. In the latter there is an electric lamp G, and lens, H. The light from the lamp is focused by the lens and sent across the uptake through the smoke, and through a glass plate J, on to a non-conducting strip D wound with selenium wire. Through this wire there circulates a current derived from the lighting mains of the ship. It is well known that the resistance of selenium varies according to the amount of light to which it is exposed, being low at high light intensities



and higher at low intensities. Naturally, when the funnel is full of thick smoke, the amount of light which reaches the selenium is small, and therefore the current increases. This current passes through a galvanometer L, the scale of which is divided up into dark, medium, light and clear, and, as this galvanometer is fixed in the stokehold, the stokers can at once see the effect of the firing. By means of a potentiometer K the current in the galvanometer can be adjusted to suit the readings desired. To prevent accumulations of soot in the boxes F and B, compressed air from the stokeholds is led to them through the pipes I and E, which keep a constant current of fresh air passing from the boxes into the uptake. There is also a sheet of glass in front of the lens and another in front of the selenium cell, and both these can be readily withdrawn for cleaning should they become obscured. The apparatus was the subject of a paper read by Rear-Admiral R. T. Hall, of the United States Navy, before the twenty-fourth meeting of the Society of Naval Architects and Marine Engineers in New York.

SHIPBUILDING NOTES.—France is about to follow the example set by England as regards the building of standard mercantile vessels. A committee comprising representatives of dockyards and the private shipbuilding industry has reported in favour of building series of standard vessels. A sub-committee is to decide upon the actual types to be chosen, dimensions of plates, boilers, &c., and the scheme is then to be realised with as little delay as possible. The Austrian Lloyd, in spite of the war, is stated to be busily engaged in extending its fleet. At the company's new yard 4 steamers for the Indian traffic, each of 8,000 tons and for 250 passengers, are said to be in course of construction. At the San Rocca yard 5 steamers of 10,000 tons each are reported to be in hand, whilst a further 8 vessels of 8,500 tons are being built elsewhere for the company, making a total of 17 steamers, with an aggregate tonnage of 150,000 tons. With reference to the large Norwegian contracts for new vessels, these are stated to amount to an aggregate of 1,300,000 tons deadweight, of which 800,000 tons have been entrusted to yards outside Europe, *i.e.*, in Canada, the United States and Japan, and 320,000 tons in European yards outside Norway. Owing to the scarcity of labour prevailing at all shipbuilding establishments all over the world, two years, in numerous cases, will have to lapse before the vessels ordered can be delivered.

SALVAGE EQUIPMENT USED IN RAISING SUBMARINE F-4., U.S.N.*

By NAVAL CONSTRUCTOR J. A. FURER, U.S.N., Member.

THE salvage methods used in raising wrecked vessels may be divided broadly into two classes. The most commonly applied method consists of restoring the buoyancy of a sufficient number of flooded compartments to float the vessel. This can be done in a number of ways. The usual method is for divers to make temporary repairs to the damaged underwater body. The compartments affected are then pumped out. More recently, successful wrecking jobs have been accomplished by sealing the decks over the flooded compartments and expelling the water through the damaged bottom by means of compressed air supplied from a tender. In cases of ordinary grounding, where perhaps no serious damage has been done to the underwater body, the vessel can often be sufficiently lightened by transferring or jettisoning enough cargo, or other heavy weights, to permit hauling the ship off at high tide. All of these methods fall under the general head of restoring lost buoyancy.

The second method consists of mechanically lifting the sunken vessel off the bottom and towing it into shallower water, or into dry dock, suspended from the lifting apparatus. This method, while it is not applicable to very large vessels, may be the only method possible under the circumstances. This was the salvage method that had to be used in raising the F-4.

The submarine failed to return from a submerged run made outside of Honolulu Harbour on March 25, 1915. The vessel was definitely located on the following day, in 304 ft. of water. After making a number of fruitless attempts to drag the submarine into shallower water by means of sweeps, it became apparent that direct lifting was the only practicable salvage method.

Description of Windlass Salvage Method.—The problem consisted of lifting 260 tons, the submerged weight of the submarine. Ordinarily, in the lifting method, surface pontoons are used for salvaging sunken craft. The lifting cables or chains are taken to the pontoons and are hove as taut as possible at low tide. As the tide rises the buoyancy of the pontoons lifts the craft clear of the bottom. The pontoons with their suspended load are then towed into shallower water until the wreck is again grounded. At the next low tide the chains are again hove taut and the process is repeated. Generally, also, the pontoons are equipped with flooding and pumping arrangements so as to increase the lift that can be obtained at each tide.

Salvage pontoons of this kind were not available in Honolulu. They would not have been altogether suitable in any case, because the difference between high water and low water off Honolulu is only about 1½ ft., and therefore practically all of the lift would have had to be accomplished by the difference in draught of the pontoons when flooded and when dry. As there is always a considerable amount of slack to be removed from lifting gear before it takes up the load, the result would have been a very limited lift at each step if this type of pontoon had been used.

There were, however, on hand locally, two bottom dumping mud scows of rugged construction. These scows were 104 ft. long by 36 ft. beam by 13 ft. deep. The scows had four mud-pockets, each about 24 by 13 ft. at the top and sloping to 11 by 13 ft. at the bottom. These scows were selected for the weight-carrying units of the salvage plant. Details of the scows are shown in Figs. 1 and 2 on page 560, and Figs. 7 to 9 on page 570. The scows were of ample strength and capacity to carry the load when distributed to the main strength members of the structure. Their adaptation for the job consisted of providing them with suitable lifting gear.

Briefly, the salvage method consisted of sweeping four wire hawsers under the vessel, two forward and two aft. The ends of these hawsers were brought up through the central mud-pocket openings of the scows and were then attached to specially constructed windlasses mounted over the pockets. Two windlasses were installed on each scow, one for each hawser. By winding up the hawsers on these windlasses the vessel was thus lifted in the loops of the four slings (Fig. 1, page 560).

Description of Equipment Scows.—Five 30-in., 100-lb. I-beams were used for the windlass foundations on each scow. Three heavy angles were fitted across the tops of the I-beams to resist racking. The ends of the beams were secured to the mud-pocket coamings by drift bolts and were braced by 12 by 12-in. timbers. The middle I-beam was supported throughout its length by the division bulkhead between the two central pockets. The two I-beams at the ends were supported by a timber truss for transferring part of the load to the mud-pocket framing of the scows.

The windlasses were made from sugar-mill shafts which were found in stock in Honolulu. These shafts were 13 ft. long by 14⅛ in. diameter, after being turned down. The shafts themselves formed also the barrels of the windlasses. Although a diameter of 15 in. is far too small to fulfil the theoretical requirement for winding up cables of the size used, it nevertheless proved satisfactory. Of the four slings two were of plough steel. These stranded to some extent, but in no instance did a cable fail entirely due to the short nip resulting from the small radius of the bend over the windlass barrel. This impairment ruined the cables for further use over the length affected, but this was a small matter as compared to the cost and difficulty of building windlasses conforming in diameter strictly to theoretical requirements.

The turning effort was applied to the windlasses by means of a bull wheel fitted to one end of each shaft. The wheels were built up solid, of such steel plates as were locally available. The material used consisted of ten ¾-in. plates for the core, with ½-in. plates for the cheeks. The core was lined with Douglas fir, so as to provide a reasonably smooth barrel for the bull rope.

The windlasses were supported by three cast-iron pillow blocks bolted to the I-beams. Instead of fitting caps over the bearings to keep the shafts from rolling out, two 1¼-in. nickel steel U-bolts were fitted over the journals adjacent to the bull wheels, with an additional U-bolt over the middle bearings. The tendency for the windlasses to leave their bearings existed only when the bull wheels were locked during the fleeting operation mentioned below. If it had been feasible to lock the shafts at both ends at a radius greater than the radius of the line of action of the lifting hawsers, no such tendency would have existed. As it was, an uncompensated moment tending to roll the windlasses out of their bearings existed with the hoisting slings in certain positions, namely, when the line of action of the active forces lay outside of the triangle formed by the three bearings and the locking pin support. The U-bolts proved adequate, except in one case, when a shackle in the running gear carried away, permitting the windlass to back down suddenly on to the locking pin. The U-bolts in this case snapped off and the windlass jumped the bearings, fortunately without doing much damage.

Power was supplied on each scow by a two-drum 8 by 10-in. hoisting engine. The drum lines consisted of ⅝-in. plough-steel wire rove up to triple blocks. The running block of the purchase was shackled to the bull rope. This purchase, in conjunction with the multiplication of power due to the diameter ratio of the bull wheel and windlass barrel—namely, 50 to 15 in.—was sufficient to wind up the load on one of the scows. On the other, due to the design and condition of the engine, a luff had to be clapped on to the purchase further to multiply the power. The distance between the triple blocks placed a limit of three turns on the number of revolutions of the windlasses obtainable without fleeting the tackles and re-winding the bull ropes. When the running blocks of the purchases had reached the end of their travel, the windlasses had to be locked to keep them from unwinding. The purchases were then overhauled by means of 4-in. manilla lines taken to the nigger-heads of the engines. The bull rope was now unshackled, rewound on the bull wheel by hand, and again shackled to the running block of the purchase ready for another lift. The large lead block for the bull rope is shown in Fig. 1, page 560. These lead blocks were built specially for the job and were so designed that the bull-rope socket could be dropped through the score of the block without coming up on the cheeks.

The locking device for the windlasses consisted of a nickel steel pin slipped through a hole in the bull-wheel disc and supported by pillow blocks resting on the foundation I-beams. Four holes were bored in the wheels so as to make it possible to lock the windlasses every quarter turn. A pawl and ratchet would have given a greater range of locking positions, but would have introduced undesirable elaboration into the design and construction of the gear.

In order to provide a margin of reserve power for starting the vessel, provision was made for using the buoyancy of the scows. A flood valve was fitted in the bottom of each scow and pumps were installed on deck for unwatering. Stability calculations indicated that the scows would be unstable with the load suspended from the windlass shafts because of the internal free water surface. In order to counteract the upsetting moment due to the negative metacentric height under these conditions, should it become necessary to flood the scows, heavy timber cribbing was fitted around the bottom of the mud-pockets for restricting the swing of the lifting hawsers. This timber cribbing also served the purpose of protecting the structure of the scow itself from the cables. The cribbing consisted of 12 by 12 in. Douglas fir timbers. It was found necessary to flood a scow only once—to relieve the strain on a jammed hawser. Figs. 1 and 2, page 560, show some of the details referred to above.

Lifting Hawsers.—Six cables as follow, each from 900 to 1,000 ft. long, were used for lifting at one time and another: One 2⅛ in. plough-steel, one 2-in. plough-steel, two 2¼-in. galvanised crucible steel, and two 2¼-in. galvanised crucible steel hawsers.

The two plough-steel hawsers, especially the 2⅛-in. hawser, proved the most satisfactory, because they resisted chafing to a much greater degree than galvanised wire. On the other hand, the plough-steel cables were much harder to handle and to sweep because of their stiffness. Splicing the plough-steel cables proved quite difficult, much more so than splicing the galvanised cables. The 2⅛-in. plough-steel cable showed a somewhat greater tendency to strand at the windlass shafts, due to the short nip, but the stranding was not sufficient to cause the cables to part at the upper end.

The hawsers were attached to the windlasses by means of 2⅛-in. hook bolts. These hook bolts were fitted through holes drilled in the shafts close to the bearings, as will be noted from the plans and photographs. By setting up on the nut of the hook bolt the hawsers were squeezed down on the shafts and thus kept from slipping by friction. The hawsers were further backed up by two cable clamps secured close to the hook bolts. On several occasions the hawsers started to slip through the hook, but held as soon as the cable clamps took up. Three dead turns of the lifting hawsers were allowed before taking up the load.

Dredge used as Working Base.—On account of the great depth of water, it was impracticable to anchor the scows over the submarine while securing the lifting

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* Paper read at the 24th general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1916.

SALVAGE EQUIPMENT USED IN RAISING SUBMARINE F-4, U.S.N.

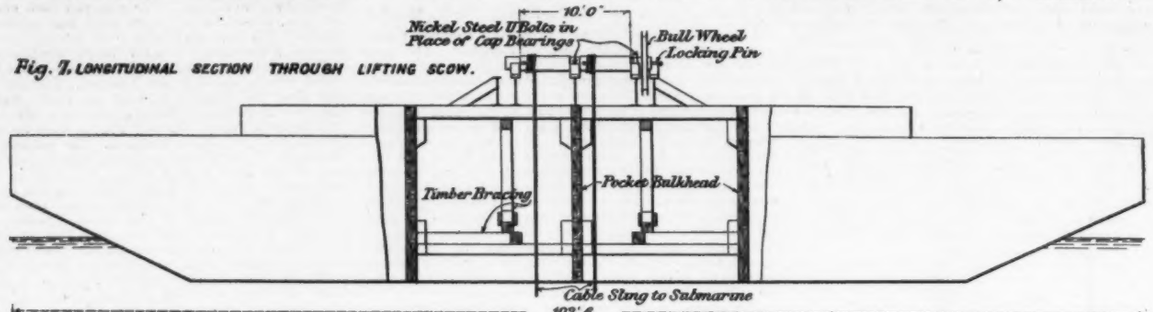


Fig. 7. LONGITUDINAL SECTION THROUGH LIFTING SCOW.

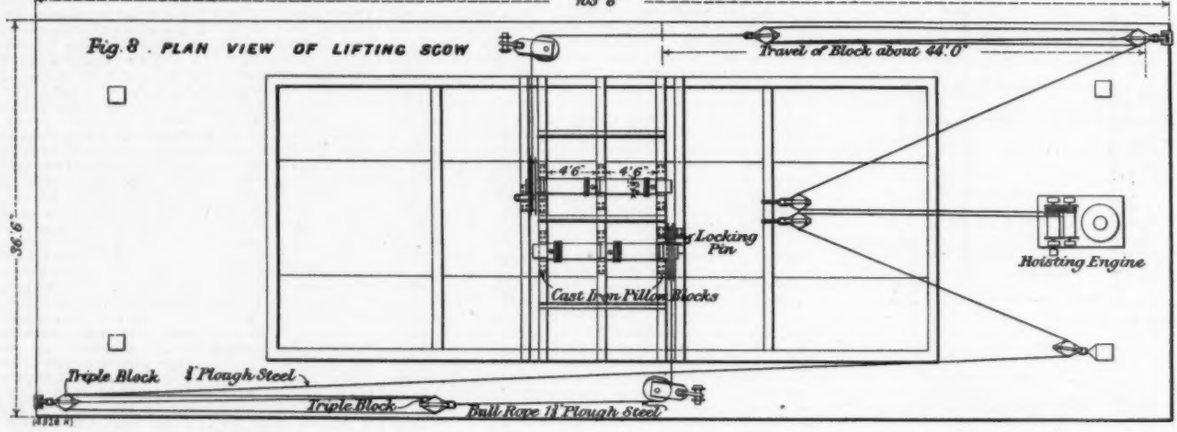


Fig. 8. PLAN VIEW OF LIFTING SCOW

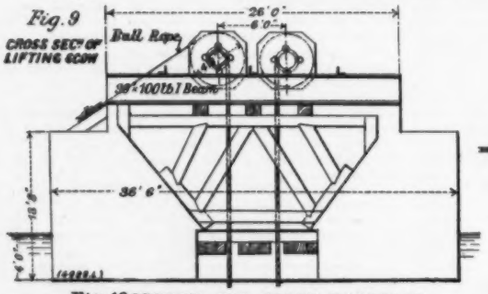


Fig. 9 CROSS SECTION OF LIFTING SCOW

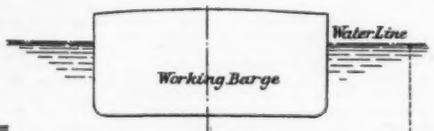
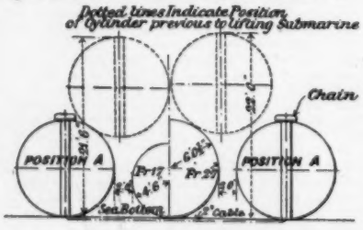


Fig. 10 SECTION FOR AFTER CYLINDERS

Fig. 11. SECTION FOR MIDSHIP CYLINDERS

LENGTHS OF CABLE.

No. of Frame.			Distance between Chain Stoppers.	Length of Cable W.L. to W.L. in Position A.
			Feet.	Feet.
17	...	...	48	117
27	...	...	51	120
43	...	...	60	125
53	...	...	60	125
71	...	...	49	118
81	...	...	46	115



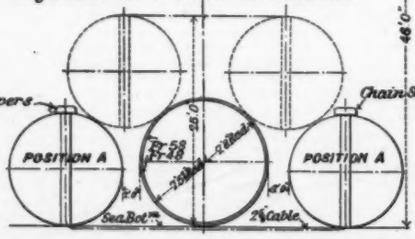
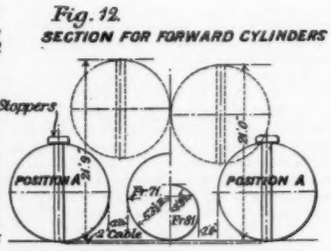
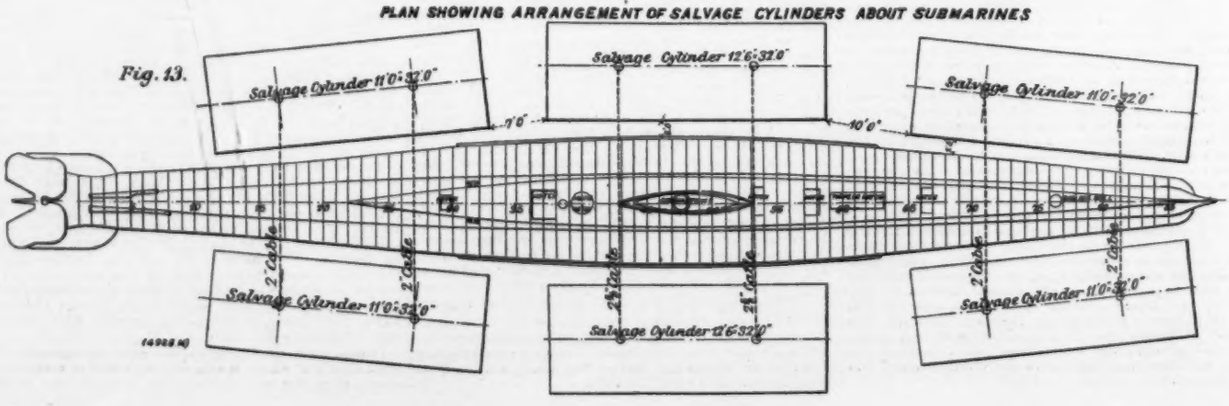


Fig. 12. SECTION FOR FORWARD CYLINDERS



PLAN SHOWING ARRANGEMENT OF SALVAGE CYLINDERS ABOUT SUBMARINES

Fig. 13.



slings to the windlasses. Also, the scows did not have on board a power plant and other facilities for taking care of the small jobs constantly arising. It was therefore necessary to have a well-equipped wrecking craft anchored in the immediate locality of the vessel which could be used as a base for conducting the salvage operations. A dredge equipped with an adequate power plant, including a dynamo, was used for this purpose. The dredge had a 10 by 14-in. hoisting engine geared to six drums, any one of which could be used independently of the others. The deck leads were so arranged that drum lines could be taken over the ends and sides of the craft advantageously.

From previous experience in attempting to anchor where the submarine lay, it was obvious that the dredge could not be moored in the customary manner on account of the great depth of water to seaward. The expedient adopted was to use the submarine itself as the seaward anchor. This was accomplished by sweeping a wire hawser around both the bow and the stern of the vessel. These hawsers were taken over the end log of the dredge and were secured to timber heads by chain stoppers, or to the drum lines. The inshore mooring for the dredge consisted of an anchor with a wire anchor line leading to one of the drums.

Plain wire hawsers of the sizes mentioned were first used for lifting the submarine. These hawsers were swept under the vessel by tugs. The ends were then temporarily transferred to the dredge. Divers were sent down after each line was swept into place to report on its position. Considerable difficulty was experienced in locating the lines correctly at the great depth in which the vessel lay.

The diving on this job established a new record. The Bureau of Construction and Repair had been experimenting with deep-sea diving for some time prior to the loss of the F-4. It so happened that these experiments, together with the development of the special equipment needed, were brought to successful termination just before the accident. A party of specially trained men was sent to Honolulu from the New York Navy Yard, where the experimental work had been done.

After the first few dives it was realised that the divers would not be able to do manual work at this great depth, because of the extreme exhaustion following such work. This is not so surprising when it is remembered that at 300 ft. a diver is breathing air under 135 lb. pressure. The experimental work which had been done indicated also that it was not safe to keep divers on the bottom at this depth for any great length of time. On this job the men were not kept on the bottom intentionally more than from 10 to 15 minutes at a time. It was fortunately not found necessary to call on the divers to do manual work while the vessel was in deep water. Their function consisted of observing the location of the lines and reporting on the steps necessary to bring them into the positions desired. Their services in this connection were invaluable, as it would not have been possible to have adjusted the slings without their reports.

All four hawsers were finally swept into position and were transferred to the scows. Some time had elapsed since the first hawser had been placed under the submarine, consequently this first line was no doubt considerably chafed before lifting operations were started. Such impairment was considerably augmented at just this time by bad weather, which increased the motion of the scows and dredge. After lifting about 12 ft. and towing inshore a corresponding amount, one of the galvanised hawsers parted. On being brought to the surface it was quite evident that the stranding had occurred at the bilge keels. Its replacement was somewhat delayed by the weather, but this was finally accomplished and another lift was made. A hawser again parted and could not be immediately replaced on account of bad weather. While the scows were riding out the weather, one cable after another parted, the last to go being the 2¾-in. plough-steel cable. Altogether a lift of 25 ft. was accomplished with the wire hawsers.

Chain Slings.—In view of the rapid impairment of the cables by chafing, a 15-fathom shot of chain was next inserted in the middle of each sling where it passed under the submarine. For this purpose 2¾-in. stud-link anchor chain was used. The broken hawsers were used for the pendants of the slings. Considerable difficulty was experienced in sweeping the combination chain and wire slings into place, partly because the submarine had shifted its position and now lay with one propeller buried in the sand. After working 21 days all four slings were again in place and lifting operations were resumed.

Good progress was made in hoisting and towing to shallower water. A depth of 50 ft. was reached close to the harbour entrance, when a heavy ground swell and bad weather set in very suddenly and wrecked the whole operation. In order to save the scows from being washed up on the reef the hoisting slings had to be cast off and the scows towed into the harbour. After a number of days the sea calmed down sufficiently to permit divers to examine the vessel. They reported that the shell had collapsed in the wake of the former position of the forward slings. This was caused by the violent surging of the forward lifting scow in the surf waves just before the slings were cast adrift.

On taking into consideration various phases of the situation, it was decided to change the plan of operations. In the first place, the months of June and July are the surf months on the south side of the Island of Oahu. A heavy swell can, therefore, be counted on most of the time during these months, off the entrance to Honolulu Harbour. It was considered likely that new lines could not be placed under the submarine and taken to the scows in the short intervals of smooth weather. This operation, from previous experience, was apt to take a number of days, hence there was danger of getting caught suddenly at any time as before.

The strongest reason, however, for changing the salvage plan was that the submarine might break in half while being taken through the channel, if lifted by the scows. This would have blocked the harbour to navigation. To have attempted repairs to the ruptured section, in order to permit using the former method of lifting, would have involved great expense and much delay, with no assurance of success. The work would have had to be done by divers and would have been made exceedingly difficult by the undertow.

There was no water shallower than about 40 ft. in which the vessel could be landed. This was the governing factor in planning the new salvage method. The maximum draught which the floating dock in Honolulu can take is about 25 ft. 6 in. If there had been a gradual slope of hard bottom in other than the ship channel, from the resting place of the vessel to the dock, it might have been possible to use the customary pontoon method, whereby vessels are lifted 5 or 6 ft. at a time and are towed to a new landing between lifts. This plan would have called for at least one landing directly in the channel. If trouble had been experienced in making the next lift promptly, the channel would have been blocked to navigation. In the harbour itself the bottom is soft, due to silting from streams and sewers. To have landed the vessel in mud would have been extremely hazardous, because mud suction practically doubles the weight to be lifted. Furthermore, the vessel would have filled completely with mud through the large aperture, as the canvas mats placed by the divers could not be counted on to keep the opening sealed.

Submersible Pontoon Method.—It was therefore necessary to resort to a salvage method which would provide for lifting the vessel from a depth of 50 ft. to a depth of not more than 25 ft. at one step. The use of submersible pontoons offered the best solution of the problem. The plan adopted called for the use of three pontoons on each side of the vessel connected in pairs by chains passing under the boat and up through hawse pipes in the pontoons. These pontoons and their application in the undertaking are shown in Figs. 3 to 5, on page 560, and Figs. 14 to 34, on Plate XLVI, whilst their disposition is shown in Figs. 10 to 13, on page 570.

The principal considerations which governed the design of the apparatus and the plan of operations were:—

(*a*) A sufficient factor of safety had to be provided in the gear and in the capacity of the pontoons to insure freedom from breakdown at the final operation of unwatering the pontoons. Account had to be taken of the fact that the stresses coming on the apparatus would be violent and sudden at times.

(*b*) A plan had to be followed which would reduce the underwater work to a minimum, and which would not unnecessarily endanger the lives of the divers. These considerations ruled out any method calling for actual connection of the lifting chains to the hull of the vessel. It also ruled out making shackle connections to the pontoons. Any attempt to make such connections would have been dangerous and probably altogether impracticable, as the divers would either have had to work between the submarine and the pontoons, or under the pontoons, while these were suspended from above and were consequently pumping up and down in the swell. This consideration led to the use of chains, which were merely rove under the boat and brought up through hawse pipes in the pontoons. The divers were therefore able to work in comparative safety on top of the pontoons while attaching the clamps to the chains as described below.

(*c*) It was necessary to provide means for reeving the chains under the boat with accuracy in predetermined locations, and it was also necessary to land the cylinders within a few feet of their lifting positions. This required the use of a flexibly moored wrecking barge over the submarine.

(*d*) The entire plan had to be based on the proposition of completing the work on and under the water with the greatest expedition possible once it was started, because of the danger of being overtaken by heavy seas at any moment. It was particularly important that once the first pontoon was landed there should be no delay, because a heavy swell would probably have wrecked the pontoons against the sides of the vessel.

Description of Pontoons.—Four of the pontoons, the bow and stern pairs, were made 32 ft. long by 11 ft. in diameter. The other two were made the same length but were 12 ft. 6 in. in diameter. The buoyancy—that is, the lifting capacity—of the 11-ft. cylinders was 63 tons, and of the larger cylinders 84 tons. The combined lifting capacity of the four pontoons was 420 tons. This provided excess capacity of 160 tons over the estimated weight of the submarine. Not only did this margin insure the necessary pull which might be needed to start the vessel, but it also provided for any failure to realise all the buoyancy available which would result should any of the cylinders become cockbilled to such an extent as to make it impossible to unwater them completely. It was correctly assumed that the full lifting capacity of the cylinders could probably not be developed, due to this cause. The weights of the cylinders were 63,000 lb. and 73,000 lb. respectively. The pontoons and their collateral equipment are shown on plans reproduced in Figs. 14 to 34, on Plate XLVI.

Securing the pontoons to the submarine was one of the most important features of the salvage arrangements. The plan adopted was very simple and proved entirely successful. Chains were rove under the vessel and, while the pontoons were afloat, were brought up through the hawse pipes already mentioned. These hawse pipes were 12 in. in diameter, fitted 8 ft. from each end of the cylinders. They were built up of steel castings connected by 12-in. pipes. After the pontoons had been landed on the bottom, cast steel clamps were bolted around the chains just above the hawse pipes. The clamps were made in halves moulded to the shape of the links. The two halves were drawn together and kept from spreading by four heavy bolts. The clamps were of such length that they bridged the hawse pipes and therefore could not slip through when loaded. Fig. 3, page 560, shows a clamp attached to one of the chains. The details of this feature will be illustrated later.

Fifteen-pound plating was used for the shell of the pontoons. The frames, consisting of 5 by 3-in. angles, were spaced 2 ft. apart with web frames in the wake of the hawse pipes. Fore-and-aft girders of 12½-lb. plating were fitted 90 deg. apart. These girders and the web frames were riveted to the lugs of the hawse-pipe castings, thus providing a very substantial construction for the support of the large concentrated loads at these points.

A transverse watertight bulkhead was fitted at midlength, dividing the pontoons into two compartments so as to facilitate sinking and blowing out. Without this bulkhead the cylinders would have been difficult to handle while being lowered into place, as there would have been no way of adjusting the trim. Two tons of concrete ballast were placed in the bottom of each so as to provide a certain amount of pendulum stability, otherwise they would have rolled too freely. A 4-in. flooding and discharge valve was fitted at the bottom of the end bulkhead of each compartment. Operating rods were provided for manipulating these valves from on top of the pontoons. A ¾-in. valve was fitted for each compartment, close to the middle bulkhead, for venting and for attaching the blowing-out hose. These valves were located in this position so as to keep them clear of the lines and the chains.

The outside of the pontoons was sheathed with Douglas fir 4 in. thick, applied in widths of 3 in. The use of narrow widths made it unnecessary to work the planks to the curvature of the cylinders. The sheathing was not attached directly to the plating, but was held in place by ½-in. galvanised wire rope. The object of the sheathing was to prevent local damage to the plating in case the cylinders happened to land on anything sharp. The sheathing also served as chafing gear between the pontoons. The value of this feature was fully demonstrated in the actual salvage operations. In the case of all of the pontoons the wood on the side towards the submarine was so badly abraded that it is safe to say that the cylinders would have sprung leaks and possibly would have been punctured if this safeguard had not been applied. The object in not attaching the planking directly to the shell plating was to eliminate the danger of pulling out or loosening the bolts. A leaky bolt would have been as disastrous to the success of the undertaking as a puncture in the shell plating. The sheathing was fitted in four lengths, each section being held in place by three wire-rope straps. A plank runway was fitted on top of the pontoons so as to afford the divers a level platform to stand on while placing the clamps.

The valves in the end bulkheads were protected by heavy timbers. These timbers also served as fenders for the ends of the pontoons. The valve-operating rods and end timbers were not placed vertically. This was necessary in order to clear the pads at the upper ends of the bulkheads. Three pads were fitted at each end. The side pads were intended for lashing across from one cylinder to its mate on the other side of the submarine. Such lashings were necessary only while the cylinders were resting on the bottom, in order to keep them snugly in position.

Figs. 4 and 5, on page 560, show the pontoons in various stages of construction.

One of the essential requirements of the plan of operations was that the lifting chains and pontoons should be placed accurately in predetermined positions with regard to the submarine. This called for mooring the salvage craft, which was used as the working base, to four buoys with control for shifting in any direction desired. Four wooden mooring buoys 10 ft. 6 in. square were built for this purpose. These buoys were anchored 45 deg. off the port and starboard bow, and 45 deg. off the stern of the submarine.

The salvage craft consisted of a wrecking barge, which had formerly been a dipper dredge. This barge was 98 ft. long by 35 ft. beam. It was equipped with a heavy A-frame and a substantial boom. The hoisting machinery on the barge consisted of two engines, each having two drums, of ¾-in. plough-steel wire rope. By taking the mooring lines to the niggerheads of the engines, the barge could be shifted conveniently. Special lead blocks and sheaves were rigged for handling the chains and for lowering the pontoons.

For the bow and stern pontoons 2-in. chain was used. As the lifting capacity of the middle pontoons was considerably greater, 2¾-in. chain was used for the latter. All six chains were rove under the boat before any of the pontoons were placed. Divers had to tunnel under the vessel to place several of the chains, but otherwise the work was accomplished without much difficulty by means of the special rigging provided on the wrecking barge.

After the pontoons had been placed in position the use of compressed air taken from torpedo flasks was decided upon *as* the simplest method for unwatering them; the battery of flasks is shown in Fig. 6, page 560, and the successful results obtained by these arrangements are shown by the final placing of the wrecked submarine in the harbour.

(To be continued.)

GERMAN WAR PROFITS.—The Schwelmer Iron Works, Schwelm, Westphalia, have distributed a dividend for last year of 16 per cent., against 8 per cent. for the preceding year, although expenses were more than double those for 1914–15. The works have principally been engaged upon the manufacture of war material and the current year promises well.

BATTLESHIP DESIGN.*

Military and Technical Considerations of Battleship Design.

By Naval Constructor R. D. Gatewood, U.S. Navy.

The whole history of warship design has been a long series of steps toward increased displacement, and, except for our own battleships Idaho and Mississippi and one or two classic examples abroad, there have been thus far practically no backward steps. By studying, even casually, the progress of the science of building warships, one is at once struck with the fact that the improvements effected in the various types have been made possible largely through this increase in displacement. The true influence that may be ascribed to increased size has been greatly confused because of many concurrent changes in other features of ship design and operation; stronger materials have made it possible to build lighter hulls, to use higher steam pressures and to instal more powerful guns; new types of propulsive machinery have resulted in increased speed or greater fuel economy; improved processes of manufacture have decreased cost of construction. Always, however, an inevitable law of growth has asserted itself and each successive vessel of every class has been larger than its predecessors.

In the case of battleships the tendency toward greater displacement would have been even greater were it not for two very important and practical objections:—(1) The extreme reluctance on the part of governments to spend such large and always increasing sums on single units of power; (2) the great difficulties in providing docking and harbour accommodation for vessels of the giant size demanded by those responsible for using these vessels in battle. Means have been devised, as, doubtless, means will continue to be devised, to overcome these objections, but is there not a limit to this increase in dimensions? If so, what are the governing considerations that are likely to determine this limit?

The problem of the United States, or indeed of any other country, is not so much whether its needs may be served best by large or small battleships, because, after all, the terms "large" and "small" are vague and relative in the extreme, but, rather, What are the minimum dimensions of the ship that will best meet our needs? These dimensions are influenced and determined by four factors:—(1) Our national policies; (2) considerations of strategy and tactics; (3) technical limitations; (4) cost. Let us cast aside all preconceived ideas as to size and analyse with an open mind the influences of each of these governing factors on the military and technical characteristics of battleship design. From the facts developed by this analysis let us then arrive at our minimum dimensions, bearing in mind always that the design thus determined merely gives "expression to the technical ideas and intentions of the epoch."† Also, that one should "hesitate to go on record for all time, as the rapid changes in conditions, improvements in material, and increase in knowledge make it desirable to reserve the right to change one's mind in order to keep up with, or go ahead of, the procession."‡

Policy and Ship Design.—Fundamental questions affecting a State's welfare, comfort, and sometimes its very existence—questions that are the living embodiment of the will of its people—are called its policies. We have gradually accumulated a set of policies giving us contact with many other States along virtual frontiers approached in extent by those of England alone. By virtue of certain geographical, racial and economical conditions over which we have no appreciable control these policies now conflict, and will continue to conflict, with the vital interests of various other world States. In the analysis of the relative seriousness of these conflicts, the statesman should reason out which State is likely to be our most probable opponent, and then should adopt a definite naval building programme against that State. Our Congress has never done this, and yet the development of our fleet, if it is to uphold these policies, must be absolutely linked up with them.

Lacking a well-defined foreign policy, it was not until some time after the advent of the new steel navy that the United States made any material progress in the design of new types. At first, due to this lack of a definite policy to direct our efforts, we took one or two backward steps. As a natural consequence of "political drifting" we proceeded to copy foreign designs—designs embodying definite policies of foreign nations. Our needs could hardly have been expected to be met by following the policies of these nations, and there resulted several misfits. More are bound to result unless we are guided in the design of our battleships by a definite and sound foreign policy, and in the future, as in the past, we are certain to develop units and even whole classes that may be excellent specimens of naval architecture but that are entirely unsuited to the needs of the country. If this policy indicates that our most probable opponents are to be black on the one side and yellow on the other, then our battleships must be so armed and protected as to be able to meet the battle fleets of black or yellow on slightly more than equal terms. Therefore they should possess armour-piercing guns of greater power and calibre, and since, actually, our probable enemies are separated from us by the width of an ocean, they must possess such speed, endurance and radius of action as effectively to wage war in any waters of the world. Thus do our national policies exercise a very legitimate control on battleship design.

Strategy, Tactics and Design.—Besides recommending a building programme providing for the number of battleships to be constructed each year, the General Board defines the military characteristics of our battleships, namely the size and arrangement of battery, extent of protection, speed and radius of action, indicating the relative importance of the various main features. This definition of military characteristics is reached after having compared our national policies with those of other States as to the most probable sources of conflict, and after having considered the numbers and types of battleships of our most probable opponents. In arriving at these decisions the most valuable aids are the data derived from the analysis of the strategical problems and tactical studies of the war game worked out either by the game board of the War College or by the movements of actual ships of the fleet simulating a naval engagement. These studies have shown conclusively that under modern conditions the gun is the principal weapon of the battleship, and concentration of superior gun fire at the decisive point at the critical time is always the key to victory. With equal units, naval gun power can be assumed to vary as the square of the number of guns that can be brought to bear.* The mere possession of a greater number of units is useless unless this superiority in number can be employed in a concentrated way at the proper time. There should be no reserves in a naval battle. "The entire force should be brought into action as nearly simultaneously as possible, so distributed as to afford mutual support, and, if practicable, in such manner as to isolate a part of the enemy from the battle while the remainder is being defeated." Reasoning from the above premises, it is obvious that concentration of armament constitutes an overwhelming advantage and is, in fact, an absolute necessity. The great length of battle line and the great difficulties in manœuvring due to the number of units in the present-day fleet imperatively demand that, from the point of view of gun fire, as many main battery guns as possible should be concentrated on as few units as possible.

Armament.—As long as the gun continues to be the major weapon, the main function of the battleship will be to provide the best possible platform on which to bring it into action. Our guns should possess greater power and destructive effect than those of our most probable enemy, and, since they are now no larger, we must allow for even greater calibres than we have heretofore used. While it is true that in penetrative effect the 14-in. gun at probable battle ranges can pierce any armour that it is practicable to mount in a ship, still, if we accept the principle of maximum destructive effect, we are led almost inevitably to a 16-in. calibre. Such a gun is well within the limits of the present state of the ordnance art, and possesses 30 per cent. more destructive effect than the present 14-in. gun of our most probable enemies. The rapidity of fire of the larger gun can be made sensibly equal to that of the smaller, and the heavier weight of projectile will allow us to adopt a relatively low muzzle velocity, by means of which both erosion and dispersion will be diminished. Such a gun possesses a materially greater range, and the priority of gun fire thus gained constitutes a material advantage.† It also possesses a greater probability of hitting at long range, and one of the most significant lessons of the European War has been that engagements have been fought and decided at 16,000 yards—a range nearly 3 miles greater than our past estimate of probable battle range. There is a further reason why we, of all nations, should adopt the larger calibre. Such a gun materially increases displacement and cost. When the present war is over we shall be the richest of nations, and therefore best able to afford the outlay incident to the adoption of the larger gun. Politically, therefore, this may be highly advisable, because of the depressing financial effect on possible enemies similar to that occasioned by the construction of the Dreadnought class by England.

Disposition and Number of Battery.—Bearing in mind the value of concentration of armament and having decided the calibre of the main battery, we come to the best arrangement of the guns. This is largely a function of the battle formation, and until such time as this shall seem to be logically other than line or column of divisions, or simple column, our centre-line vertical-echelon disposition seems best. The question of just how many guns can be advantageously mounted is hardly subject to abstract determination, but it must be quite plain that there is a point at which, after considering the other elements of a design, more guns would only result in a positive loss of efficiency. From a purely constructional point of view, this point has been reached with the four-turret centre-line mounting. So overwhelming, however, are the arguments in favour of maximum possible concentration, and so great a length must be provided to obtain the desired speed, that it will probably be best to add one more centre-line turret. This is particularly necessary if the 16-in. calibre be adopted, because the problems of mounting such guns in triple-gun turrets are not yet solved, and in no other way can the demands of concentration of armament be satisfied.*

Speed.—For both strategical and tactical reasons high speed is extremely desirable. If we accept the principle that an active offence is the best defence, speed is essential both for bringing the enemy to action and for maintaining the most suitable range during action. Moreover, speed, when employed in skilful manœuvre, assists us to gain that relative numerical superiority which is so essential for concentration. Later on it is proposed to recur to this question of speed in considering the length of battleships, and when the excessive cost of even 2 knots greater speed than that of the enemy is appreciated, it is altogether probable that we should rely on fast battle cruisers to gain the above advantages rather than attempt to attain too great superiority of speed with the battleships. No other single feature of a ship has so large an influence on displacement, and every fraction of a knot sacrificed will allow the displacement to be reduced many hundreds of tons. Great ships of this type will always cruise in squadron, and the speed of the squadron will be the speed of the slowest unit. This speed is a function of so many variables—condition of bottom, quality of coal, skill of personnel, condition of machinery, danger of machinery troubles at maximum speeds—and the cost incident to any material increase is so unreasonably great that it would seem wiser to adopt comparatively moderate speed.

Armour.—There will always be a difference of opinion as to the relative importance of guns, speed and armour, but in no one of these three military characteristics is there such a wide divergence of views as in the case of armour. One authority advocates "external protection," completely excluding the shell; another advocates "internal protection," limiting to a minimum destructive effect after penetration; one advocates protection to vitals only, another complete protection; one advocates vertical side armour, another horizontal deck armour. All admit, however, that at the present time the gun bids fair to be the permanent victor over armour. It is not feasible to mount armour of such thickness and area as to exclude all shell, yet at least we should provide such protection to buoyancy and stability, and to magazines, fire-rooms, engine-rooms and other vital parts as will render them, as far as possible, safe from all but the largest shell at normal impact. This can be done with the least expenditure of weight by means of vertically disposed side armour. To protect against shell fragments and to preserve buoyancy we must have at least one protective deck located above the deepest possible load line. The minimum reasonable requirement of armour, therefore, aside from the local protection of turrets, barbettes, conning tower and base of smoke pipes afforded by their own armour, is a belt extending high enough above the normal load waterline to protect the stability, buoyancy and vital military features of the ship, and extending low enough to guard against underwater hits due to naval action, rolling of ship or heel due to damage. Coupled with this there should be at least one protective deck—all to be of the greatest practicable thickness.

Endurance.—Other great nations of the world, as well as the United States, have long since abandoned the fallacy of building battleships for coast defence, with consequent small radius of action. As previously pointed out, our battleships should be capable of waging successful war in the waters of our most probable enemies. Since these waters are separated from our own by the width of an ocean, the radius of action of our battleships should be sufficient to traverse this distance to and fro at probable fleet speed, with an additional 2,000 miles or so to cover the cruising that may be necessary until contact can be made with the enemy. This would hardly be practicable with a smaller radius of action than 8,000 miles at 12 knots. Fortunately the advent of fuel oil, together with increased efficiency of ship-form and propulsive machinery, renders it possible to meet this claim with comparative ease.

Protection against Torpedo Attack.—The gun seems certain to remain the supreme weapon of offence, but this superiority is challenged more and more by the formidable menace of the torpedo and mine. No battleship has ever been provided with any sure defence against either of these dangers, and the weakest feature of all existing battleships is their lack of adequate protection against underwater attack. Even now the largest unit of any fleet can be put almost, if not quite, "out of action" by a single torpedo, and in the future there is little to prevent the use of much larger explosive charges to offset any increased subdivision or underwater armour that may be provided. It seems probable, therefore, that the chief defence against this form of attack will consist in a somewhat increased speed of battleships and a cordon of high-speed units of the destroyer type. In addition to the protection thus afforded, every possible provision should still be made to minimise the results of successful torpedo attack, and it will therefore be necessary to provide suitable minute watertight subdivisions and even armour—all of which must add materially to displacement. This comparatively new effectiveness of the submarine and its weapon, the torpedo, must exercise a powerful

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* Paper read at the 24th general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1916.

† Admiral Sir Cyprian Bridge. Paper before Jubilee Meeting, Naval Architects and Marine Engineers.

‡ Ex-Naval Constructor R. H. Robinson. Paper before Naval War College, August, 1911.

* "Suppose F_1, F_2 opposed to A, all three being identical ships, each capable of firing 1 round a minute, and assumed to be put out of action by 4 rounds. A *would be destroyed by* $F_1 + F_2$ in 2 minutes. $F_1 + F_2$ would be destroyed by A in 8 minutes. Therefore $\frac{F_1 + F_2}{A} = 4$. That is, the fighting value of two vessels fighting one is four times as great as that of one vessel fighting two. Similarly, three vessels fighting two would stand to them, in point of fighting value, in the ratio of $\frac{9}{4}$." See Baudry, "The Naval Battle," page 99.

† See Baudry, "The Naval Battle," page 116.

* For further arguments in favour of restricting the number of turrets to four, see Sir William White's paper before the Society of Naval Architects and Marine Engineers, 1910, and Lieutenant Viani's paper in Supplement to *Rivista Marittima*, 1908.

influence on the size and cost of individual units, and it is not at all improbable that the eventual development of the submarine may result in driving the battleship from the sea. He would indeed be a rash prophet who would venture to predict when this will come to pass, but until then the development of the battleship type must move forward, or else the type must be abandoned altogether.

Technical Limitations.—The above are the most essential military characteristics to be incorporated into the design of our battleships, although there are many others of lesser importance that require due consideration, such as secondary battery, torpedo armament and type of propulsive machinery. After they are decided, the problem presented to the naval architect involves such technical characteristics as buoyancy, stability, manœuvring qualities and strength. On account of the great number of variables involved it is capable of numerous solutions of more or less merit, but what we are chiefly concerned with at this stage of the subject is to determine the minimum displacement on which we can expect to meet all these claims.

Design.—In the first place the design of a battleship cannot be made according to mathematical formulæ. Many years ago Rear Admiral Fiske said that he "laboured for several weeks in a persistent endeavour to arrive at some law by which, for a given size of ship, the best combination of speed, armour and armament could be determined," and that he "failed to find any such law, largely because he did not know the conditions under which the ship would have to fight." But had he known the conditions he would have been no nearer to his law. No such law exists. The several elements of a design may admit occasionally of scientific treatment by means of exact empirical formulæ—for example, the buoyancy, stability and speed. But a formula or law does not exist for combining the above elements with strength, endurance, protection and armament, and arriving at the best result. This has always been, is now, and in all probability will continue to be, a matter of opinion—or, rather, difference of opinion—and so let us leave it.

Dimensions.—Displacement is determined by the principal dimensions, length, breadth and depth, and by the form of the lines. Each dimension is determined with respect to absolutely different things, and each one must be thought out carefully by itself, never forgetting at the same time certain empirical ratios with respect to each other that have been found to exist in successful ships of similar design.

Draught.—This dimension is influenced chiefly by such practical considerations as the depth of harbours and docking accommodation. Although designed to operate normally from certain bases, it is plain that battleships should not be materially restricted in their actions to certain fixed ports. It is true that any well-devised battleship-building programme should be undertaken concurrently with a programme for increased depth of harbours and size of docks, but the practical considerations of the great cost thus involved must always exert a strong influence toward moderate draught. Having in view these reasons, it would be well, at least until harbours and docks have been further enlarged, to restrict the normal load draught of our battleships to 30 ft., the deep load draught not to exceed 32 ft.

Beam.—The question of beam, to which we now come, is determined somewhat with regard to width of docks,* but more with regard to stability, since the position of the metacentre is determined chiefly by the beam, and the metacentric height is the most important consideration affecting the movements of a ship in a seaway. The position of the metacentre varies directly as the square of the beam, so that if we increase beam, we materially increase metacentric height, initial stability, and the stiffness of the ship in a seaway. This stiffness should be ample to prevent a too great heel when turning or when side compartments are flooded, but not so great as to impair the steadiness of the gun platform and render the motion of the ship jerky and unsteady. Exact formulæ for the influence of beam on speed do not exist, but model experiments seem to bear out the fact that on a given displacement for an increase of beam of, say, 5 per cent., the effective horse-power must be increased by the same percentage if the same speed is desired, and that if length be kept constant the ratio $\frac{B}{D}$ can be varied widely without any very appreciable effect on resistance.

Length.—This dimension is influenced more by the speed than by any other feature of the design. In order to obtain high speed it is absolutely necessary to have length. To give a concrete example of this, assume that we desire 24 knots speed from a 30,000-ton ship. With a 690-ft. length the speed could be obtained with about 40,000 h.p. Keeping beam and draught constant, but shortening the length to 630 ft., there would be needed 50,000 h.p., and at 570 ft. over 80,000 h.p. would be required; whereas, if we desire only 20 knots speed, it can be obtained on a 570-ft. length with but little more than 40,000 h.p. Furthermore, not only will the shorter ship require much more horse-power for a given speed, but it affords less length for the installation of the increased horse-power, so that practically the length must be great enough to enable the necessary machinery to be installed. On the other hand, by a too great increase in length we reach a point where the frictional resistance due to increased wetted surface is greater than the gain from reduced wave-making resistance, particularly at cruising speeds. Length is not favourable for manœuvring, increasing the resistance to turning. Length necessitates a serious increase in displacement, due to the greater weight of armour and hull for the same protection and same strength.* Greater length means greater target area, and, incidentally, there are but few dry docks that will accommodate great lengths.

Displacement.—Many other features must be given their relative weight, the chief of which are seaworthiness, freeboard, and type of hull fittings, but enough has been said to indicate the principal military and technical considerations influencing and limiting battleship displacement.

Passing over the more or less mechanical end of the calculations involved, it may be stated that, in the present state of the art of the naval architect and marine engineer, it is not possible adequately to fulfil these principal claims on less dimensions than 640 ft. for length, 96 ft. for beam, and 30 ft. for draught, with a consequent displacement of approximately 36,000 tons.

Thus, although we have restricted the number of turrets to five, and the number of guns to 10, confined our armour to vitals only, used only moderate speed, and employed every technical and engineering means to reduce displacement, we have arrived inevitably at a large ship. Moreover, any ship of less displacement, that is, any "smaller" ship, must be inferior in armament, armour or speed. Any ship of greater displacement will probably involve a too great expenditure for harbours and docks, and the military gain that could be effected would not be commensurate with the increased cost and other disadvantages incident to great displacement.

Cost.—A study of the relative costs of large and small battleships should properly include not only the first or "prime" cost, but the cost of maintenance as well. Above certain displacements it should also include the cost incident to increased harbour and docking facilities, and it has already been shown that this can readily involve such a large expenditure as materially to restrict the dimensions and displacement of capital ships. As regards first cost, perhaps the briefest way to indicate the practical relation in battleship construction existing between cost, displacement and effective gun-power is to state that, by increasing the cost one-half and the displacement one-third, it is possible to produce a unit with double the effective gun fire.† Consequently, if smaller and more numerous units are constructed for the same expenditure, each with an effective gun fire equal to one-half that of our type ship, we may expect to provide only three smaller vessels for every two larger ones; and the effective gun power of the two large ships would be one-third greater than that of the three smaller ships (*i.e.*, in the proportion of 2 to 1.5). Moreover, the cost per annum of manning and maintaining the more numerous fleet will be materially greater. It may be conservatively estimated that this increased cost of maintenance of the three small ships over that of the two larger ones will not be less than 5 per cent. per annum. Assuming the life of a capital ship to be 20 years, it will cost 100 per cent. more to man and maintain the more numerous fleet. It is also to be observed that, although the cost per unit for "large" ships is much greater, the risk of total loss is correspondingly smaller on account of the better subdivision possible to provide on the larger ship, and the greater distance from the skin of the ship at which it is possible to place the boilers and magazines.

Fighting Value.—Many advantages of the larger units become greater and more accentuated when the fighting value of a fleet of units is considered. This is particularly true when we compare fleets of equal cost. It has been shown that for a given expenditure of money it is possible to provide one-third more gun power on larger vessels than on smaller vessels each of gun power equivalent to one-half the larger vessels. If the calibre of guns in the two fleets be assumed equal, then the larger ships possess a one-third greater numerical superiority. This would indicate that the fighting power of the large ships with relation to that of the small ships is in the proportion of $\left(\frac{4}{3}\right)^2 = \frac{16}{9} = 1.77$.‡ Furthermore, the destructive value of a fleet is determined not only by the fighting value of its units, but by the method of employing that fighting value. The principal factors in connection with the method of employing fighting value are (1) manœuvre, and (2) fire control. Manœuvre enables a fleet to gain that relative numerical superiority of guns required by the principle of concentration. The fewer number of units in the fleet of large ships allows a greater ease of manœuvre on account of the handiness of a short line as compared with the clumsiness of a long one, apart from such matters as visibility of signals, &c. If it be argued that the smaller and therefore more numerous fleet possesses a larger power of combination, the answer is that in a naval battle it is not power of combination that we desire but power of concentration. From the point of view of fire control, the big ship again has a great advantage. Assume three small ships fighting one large one. To anyone who has witnessed long-range target practice and attempted to spot the fall of salvos, it is at once apparent how extremely difficult, if not indeed impossible, it would be to identify the salvos of the three smaller ships as they fall about the large one, whereas the fire-control officer and spotter of the single large ship can concentrate their salvos on either one or two of the smaller ships, identifying unerringly each salvo. The advantage of the small ships due to the "dispersion of target" offered by them would be more than counterbalanced by the great handicap of being unable to identify their salvos.

Conclusion.—Since the ultimate purpose in modern war is the disruption and destruction of the organised forces of the enemy, the purpose of our battleship fleet is neither the defence of our coast, the blockade of the enemy's fleet in his ports, the capture of sea-coast forts, nor even the "command of the sea." Its mission—its sole mission—is battle, the complete and relentless destruction of the enemy's battle fleet. To this end it must possess at the outset and maintain by manœuvre during battle that relative superiority which is the key of all decisive battles by land or by sea. This can be obtained most certainly, and at a much less cost per gun, by concentration of fighting power in large units. It has been shown that the fulfilment of the present-day claims on the military and technical characteristics of battleship design imperatively demands a ship of large displacement. It has also been shown how each element of a design can be benefited by an increase of displacement. Apart, however, from this gain, the larger ship possesses certain inherent advantages over the smaller one that more than outweigh the disadvantages due to size:—Greater concentration of armament; better protection of buoyancy and stability by comparatively more minute subdivision; greater protection by armour, because the thickness of armour need not be increased with displacement, and the same area will protect a greater tonnage; more economical propulsion; greater radius of action; greater sustained sea speed under all conditions of weather; greater efficiency per gun due to the wide separation of turrets, machinery, magazines, &c., also on account of the greater safeguards it is possible to provide on the large ship with regard to the supply of power, ammunition and every other essential that serves the gun. Moreover, it is only large displacement which makes it possible to provide that adequate protection against underwater attack which is becoming more and more necessary and which cannot be provided with smaller displacements. These are the reasons that demonstrate so convincingly the value of the larger ship and that will force us inevitably to build larger and even larger units until such time as the improvement in submarine and aerial offence shall drive the present battleship type from the sea for ever.

* It is limited, for the present, at least, by the 110-ft. width of the Panama Canal locks.

* If the same percentage of side is to be protected without decreasing the thickness of armour, the weight of side armour will increase directly with the length. The increase in hull weight is due to the greater area of plating, this area increasing approximately as the square root of the length, and also to the greater thickness of plating which it is necessary to use in order to provide adequate strength to meet the bending moment, which increases roughly as the length.

† Paper by Chief Constructor F. T. Bowles, U.S. Navy, 1902; also paper presented by Professor Welsh in the spring of 1911, Society of Naval Architects and Marine Engineers. See also comparison of contemporary United States designs.

‡ See previous page.

COLONIAL ENGINEERING PROJECTS.

We give below a few data on several Colonial engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Australia.—The New South Wales *Government Gazette* publishes a Proclamation by the Governor of the State authorising the Deputy Chief Commissioner for Railways and Tramways to acquire land for the purpose of maintaining traffic on the existing line of railway between Sydney and Albury by duplicating that railway between Wallendbeen and Cootamundra, and to carry out the necessary works. The cost of completing this undertaking is estimated not to exceed 20,000*l*. The *Government Gazette* also publishes a notice of the passing of an Act by the New South Wales Parliament sanctioning the construction of a concrete and masonry dam across the Cordeaux River, in conjunction with the Sydney water supply system.

New Zealand.—The Office of H.M. Trade Commissioner in New Zealand calls attention to a notice, which appeared in the official *New Zealand Gazette*, to the effect that, as a result of a poll of the ratepayers of the borough of Wanganui (North Island), it has been decided to borrow the sum of 25,000*l*. for the following purposes:—Extension of the existing drainage scheme, augmenting waterworks, construction of a tunnel at Okehu, and for providing public conveniences.

THE WESTPHALIAN CEMENT INDUSTRY.—The Rhenish-Westphalian Cement Union has arrived at an understanding with outside works, whereby eight works, with an aggregate of 2,250,000 barrels, join the union, and, in addition, 550,000 barrels have to be divided proportionately amongst new members. The aggregate allotment of the older members is being raised for the benefit of those works, which had received inadequate allotments at the formation of the union.

SHIPBUILDING ACTIVITY IN SWEDEN.—The Grängesberg-Oxelösund Traffic Company, which controls most of the Swedish iron ore export, has now placed definite orders with the Gothenburg New Shipyard Company for 18 steamers, of which 10 are to be of 7,500 tons and 8 of 5,000 tons. The Transatlantic Steamer Company has ordered two cargo boats from the Lindholmen yard, each of 7,900 tons. The same company has also bought the second 3,000-ton boat being built at the same yard for account of the Rex Company. This is the sixth steamer of this type which the Transatlantic Company has secured, the first, the Boren, having been delivered in April of this year; the last will probably be delivered in less than a year from that date: this makes six boats of 3,150 tons each delivered to the same company within a twelvemonth, which means a record in Swedish shipbuilding.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

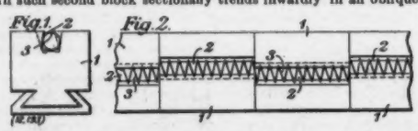
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

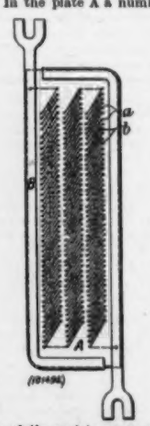
ELECTRICAL APPARATUS.

12,193/15. A. E. Woodhouse, London. Insulators. (4 *Figs.*) August 24, 1915.—The present invention relates to insulators for electrical resistances of the helical coil type. 1 designates a brick of porcelain in which an open-topped channel 2 is formed, this channel 2 extending from end to end of block 1, as shown in Fig. 2, and sectionally trending inwardly in an oblique direction towards the left-hand side of Fig. 1. A replica of such block is placed laterally and endwise reversed against the end of the block 1, as shown in Fig. 2. The channel in such second block sectionally trends inwardly in an oblique



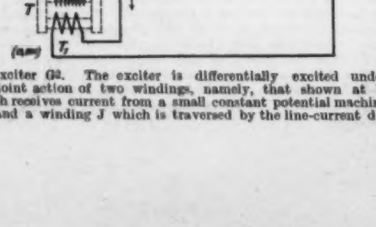
direction towards the right-hand side of the second block, and by appropriate sloping that condition is obtained that those walls of adjacent channel lengths which are on opposite sides of a coil 3 placed in the extended channel, and which project towards one another, form a continuous open-topped recess or channel into which the coil may be inserted from the front, the setting and directing of the side walls, which project towards one another being such as to leave the mouth of the channel continuously open, although somewhat locally contracted at the junction plane of adjacent channel lengths. (*Accepted October* 4, 1916.)

101,498. Clarke, Chapman and Company, Limited, and R. C. Harris, Gateshead-on-Tyne. Resistances. (6 *Figs.*) February 4, 1916.—This invention relates to electric resistances of the kind in which the conductor is supported throughout its length at both sides of a base of insulating material by threading the same through holes therein so that the conductor presents the appearance at each side of the base of a number of stitches relatively short in length. The resistance units are built up of an insulating plate A with a metal framing B round the greater part of the outer edge. In the plate A a number of rows of small



holes *a* are pierced and the resistance conductor *b* is threaded through these holes from one row to another row to form stitches in such a manner that the maximum length of conductor is used for a given size of plate, the arrangement being such that whilst the conductor is supported throughout its length, the holes do not interfere with free ventilation of the conductor at any point in its length. The stitches are parallel to one another, but inclined to straight rows of holes, so that the pitch of the latter is greater than the perpendicular distance between the stitches. (*Accepted October* 4, 1916.)

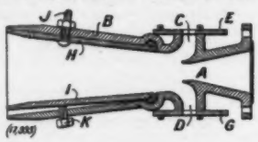
13,901/15. R. Thury, Geneva, Switzerland. Dynamo-Electric Machines. (4 *Figs.*) June 16, 1915.—This invention relates to direct current supply on the series system. The generator G1 is excited by a winding I1 that is fed from



an exciter G2. The exciter is differentially excited under the joint action of two windings, namely, that shown at I2 which receives current from a small constant potential machine G3 and a winding J which is traversed by the line-current delivered by the main machine G1. The three armatures G1, G2, G3, are conveniently mounted on a single shaft. The constant potential machine G3 may be replaced by any other source of constant potential, such, for example, as an accumulator. An adjusting rheostat is inserted at R2 in the circuit of the winding I2. Neglecting the transformer T shown in the figure, the action is as follows:—Under normal conditions the preponderant effect of I2 over that of J provides sufficient excitation to G2 to cause the latter to deliver the required current to I1. At no load the difference between I2 and J is exceedingly small, but as load comes on the line-current tends to drop, and since the effect of I2 is constant, a diminution in the effect of J occasions an increase in the excitation of I1. The excitation of the main machine G1 therefore increases as the load rises, as is desired. (*Accepted October* 4, 1916.)

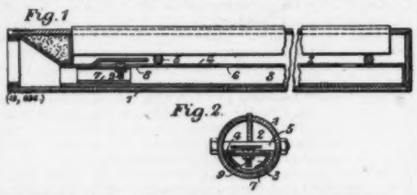
GAS-ENGINES, PRODUCERS, HOLDERS, &c.

17,993/15. T. M. Hunter, Glasgow. Gas Burners. (4 *Figs.*) December 24, 1915.—This invention relates to atmospheric gas burners of the type in which the gas is delivered from nozzles into a mixing tube in which the cross-sectional area increases gradually from the throat to the outlet end. The gas is delivered from a nozzle A into a mixing tube B of the kind mentioned. Air is admitted to the mixing tube, in known manner, by passages C, D therein at the end which is next the gas nozzle, the inlet to these passages being controlled by endwise movable apertured plates E, G. Within the tube B two plates



H, I, are hinged at their inner ends, the hinges being in recesses in the upper and lower sides of the tube B. These plates are such as to fit and cover the entire width of the inner surface of the upper and lower sides of the tube. The plates are positioned within the tube by means of adjusting screws J, K, passing through apertures in the walls of the tube. By this adjustment the area of the mixing tube B may be regulated to suit varying gas pressures, thus controlling the position where the mixture of gas and air ignites, and thereby lessening the risk of "back firing." (*Accepted October* 4, 1916.)

13,836/15. J. Keith and G. Keith, London. Gas Burners. (6 *Figs.*) September 29, 1915.—The burner tube 1 is divided longitudinally into two chambers 2–3 by the tubular diaphragm 4, of the upper wall of which bears against the transverse screws 5, the interior of the tubular diaphragm constituting the chamber 3. From the end of the tubular diaphragm adjacent to the injector (not shown) a connection is taken to the latter, so that normally the whole of the mixture passes into the chamber 3. The diaphragm 4 is apertured at intervals by means of slots 6. The slots are distributed so that normally the delivery of the mixture is greatest at the end of the burner remote from the injector. To provide for adjustment of the distribution, a valve

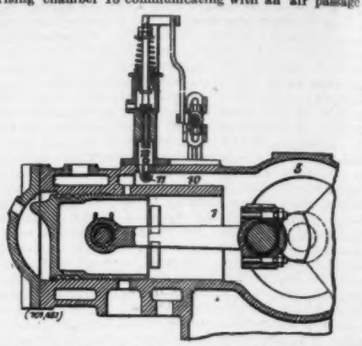


is employed for by-passing the chamber 3 and admitting the bulk of the mixture into the chamber 2, the arrangement being such that when the by-pass is fully open the maximum delivery is at the end of the burner adjacent to the injector. The valve comprises a short D-shaped tube 7 fitting into the end of the tubular diaphragm 4 adjacent to the injector, the plane portion of which is adapted to cover an aperture 8 in the plane portion of the diaphragm, thus forming a sliding damper. To provide for displacement of the damper, there is fixed to the latter a stud 9, one end of which projects through the by-pass aperture 8 and the other end of which projects into the interior of the tubular diaphragm 4, such stud being engageable by a rod pushed through the throat of the injector. (*Accepted October* 4, 1916.)

101,521. F. H. Royce, B. I. Day, and Rolls-Royce, Limited, Derby. Starting Clear Clutches. (2 *Figs.*) May 31, 1916.—*a* is the crankshaft of the engine, *a*1 the driven member of a friction-plate clutch, *b* is the starting shaft on which is cut a screw thread *c* engaging with an extension of the driving member *d*1 of the friction-plate clutch, *d*2 are the friction discs of the plate clutch, three of which engage with serrations on the crankshaft and other three with the serrations on the driving member *d*1; *k* is a pawl which engages with the ratchet *k*1 on the periphery of the driven member *d*1, and is controlled by the spring *k*2 (Fig. 2). The friction offered by the discs and parts of the clutch, together with the friction between the pawl and the

ratchet, is greater than the friction between the shaft *b* and the member *d*1. The screw thread *c* is left-handed, and accordingly, on rotating the shaft *b* in clockwise direction, the driven member *d*1 will, by the combined effect of the screw thread and of the resistance to rotation offered to it by the discs and parts of the clutch and the pawl, be caused to move axially to engage the friction discs *d*2. As the driving member compresses the plates of the clutch, the resistance to rotation of the member *d*1, and consequently the end thrust occasioned by the screw, are intensified until the shafts *a* and *b* rotate together for the purpose of starting the engine. When the engine starts, the driven member of the clutch becomes the driving member, and tends to rotate the member *d*1 faster than the shaft *b*, and this reduces and finally reverses the end thrust of the screw in the shaft *b*, and the member *d*1 is caused to move axially away from the friction discs, thus releasing the clutch. (*Accepted October* 4, 1916.)

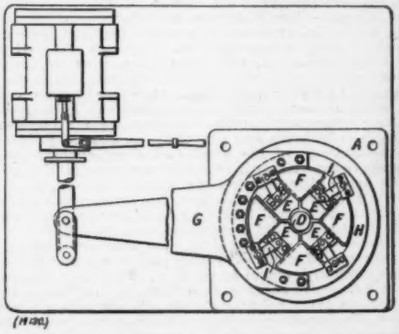
101,451. J. R. Walker and A. E. Walker, Tewkesbury. Oil Engines. (4 *Figs.*) May 10, 1916.—This invention has reference to those oil engines working on a two-stroke cycle which are designed to be driven by the internal combustion of heavy hydrocarbons which require to be heated and vaporised before or during the admission with air to the cylinders to form the charge. The invention comprises the combination of an oil-vaporising chamber 18 communicating with an air passage 10



leading from the crank chamber 5 to the cylinder 1, a hollow heating member 11 arranged in the chamber 18 and heated by the exhaust gases from the engine, and on to which member oil to form the charge is sprayed or dripped and thereby vapourised. The arrangement is such that the hot vaporised oil is carried into the cylinder by and with the hot air flowing thereto under the pressure from the crank case. (*Accepted September* 27, 1916.)

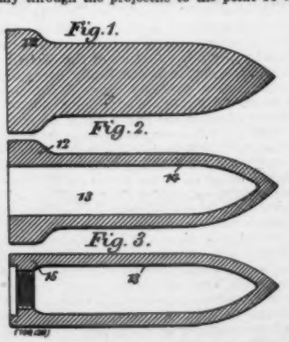
GUNS AND EXPLOSIVES.

14,130/15. T. Wood, Wigan. Projectiles. (3 *Figs.*) October 6, 1915.—This invention has reference to apparatus for pressing copper bands on projectiles. The bed A is provided with a centre recess D of such depth that when the projectile is inserted in it in a standing position the groove in the projectile is above the top of the recess. Mounted on the bed or table A are dies or followers E arranged radially around the recess D and mounted in guides or between cheeks F so that they



can be moved simultaneously towards the projectile and force the copper band into the groove. This is effected by the partial rotation of a lever G operated by steam, compressed air or hydraulic power, the operation of the lever G in one direction causing the dies or followers E through the usual ring H and toggles I to advance and force the band into the groove, while the operation of the lever G in the other direction will cause the dies or followers E to recede therefrom and enable the shell to be removed from the bed A. (*Accepted October* 4, 1916.)

100,128. Bethlehem Steel Company, South Bethlehem, U.S.A. Projectiles. (4 *Figs.*) March 2, 1915.—The solid blank shell is provided with a circumferential enlargement 12 at its base. The cavity for the charge is then bored by means of a straight through boring tool, the boring extending from the base and centrally through the projectile to the point 14 where the



tapering end of the cavity begins. Through the opening 13 a tool is inserted for shaping the inner end of the cavity. The outer or base end of the cavity is then partially closed by swaging or pressing inward the circumferential enlargement, thus forming a neck 15 to receive the fuse plug or other closure. This neck is finally threaded and shaped to receive the closure. (*Accepted September* 27, 1916.)